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Assessment of the Current False Alarm Situation from Fire Detection Systems in New Zealand and the Development of an Expert System for Their Identifications

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Abstract

This report examines the current false alarm situation from fire detection systems in New Zealand by studying the fire calls provided by AFA Monitoring Ltd from July 1999 to June 2001. The process of the developing of an Expert System for prediction the likely causes of a false alarm is also described in this report.

This study supports the hypothesis that human activities impose some impact on the occurrence of false alarms. It was also found that different building types had different reasons for their most likely cause of false alarm. For example in an industrial facility, the most likely cause for false alarm is Component Failure. The most likely cause of a false alarm varies with different types of detection systems, such as a smoke detection system is most likely to be activated falsely due to an Environmental Effect.

An Expert System is an artificial intelligent program that can be used to assist end users make decisions. In this report, a program called Expert System Builder was used. The author combined the knowledge about false alarms in New Zealand, and applied it for developing a tool that can assist the site engineer to identify the cause of a false alarm.

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I would like to give my thanks to my beloved family, my dear classmates, and my most supportive church fellows. Thank you all for supporting me through this time, I enjoyed all the tears and laughter we shared together.

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Contents

1.0 Introduction

It is not easy to give the term "False Alarm" a specific definition, because different parties have different perspectives on what they consider as a false alarm. For the purpose of this report, a *false alarm* is defined as a signal transmitted by an automatic fire detection system reporting a fire where on the arrival of the brigade an uncontrolled fire has not occurred.

In New Zealand, there is a false alarm charging policy, which is intended to encourage customers to fix their alarm systems that repeatedly give false fire signals. According to Section 47C(4) of the Fire Service Act 1975, the Fire Service has the right to charge for attendance of any brigade, where the reason for that attendance was the receipt of a false alarm of fire, and, where that alarm came from persons or equipment in any premises, the owner of the premises shall be liable to meet the charge. The typical costs of attendance are likely to be NZ$1,000 per false alarm, but there are four situations that the false alarm charges can be exceptional. Stewart [1] listed these four cases; the first case is that if a detection system activates a fire alarm due to the presence of heat or smoke from a controllable fire, which is what the system is designed to detect, this type of false alarm can be except from the charge. If the caller who activated a fire alarm genuinely thought there was a fire or emergency, the New Zealand Fire Service will not place the charge on the building users. One other case is when the fire alarm was caused by action of person(s) remote from the property such as road workers creating dust or fumes on a public street which accidentally activate the fire detection systems in the buildings nearby. The last case is when the alarm agent has accidentally set the system off. Other than the four cases listed above, the false fire alarms will be subjected to a fine.

In this report, the set of data analysed is a very comprehensive source. This database was provided by AFA Monitoring Ltd. This institution keeps the fire calls data received by New Zealand Fire Service from the buildings throughout the whole country. Where there was a false alarm, the alarm agent supposed to fill out a form to report on that incident. When the monitoring process first started, there were a large amount of fire calls that were not reported, but the reporting rate has improved with time. In the database, each system has a unique private fire alarm (FPA) number and FPA address.

In this database, the date and time of the fire calls were recorded, the types of fire detection systems, the building type (only reported after June 2000), the agent name, connection date, reason for fire call, and the description of the fire call. The fire call records are reported throughout New Zealand. This database is only available from January 1999, there being no records prior to that.

In the analysis of this data, it was assumed that the unreported fire calls with no specific reason reported have the same probability of different reasons for false alarms as the reported fire calls. But this is not necessarily true, because for the fire calls that were not reported it might be more difficult to identify the cause. There is a total of 26,824 fire calls from July 1999 to June 2001. Only about 18,000 fire calls have been fully reported. Some of the reports were incomplete; these records were omitted from the analysis. Some buildings cannot be categorised into the building type from the amount of address details and the building name. They were also left out since the building type was part of the formula to identify the cause.

No. of Completed Fire Reports	17,818
Genuine Fire Calls	749
No. of Incomplete Fire Reports	9,006
Unidentifiable Building Type	1,113
No Reason Was Given	7,893
Total No. of Fire Calls (from July 1999 to June 2001)	26,824

Table 1.1 Summary of the state of data set.

This above table shows the statistics for the fire call data used in this report, there was a total of 26,824 fire calls received by New Zealand Fire Service through fire detection systems. In these data, there were 9,006 records that had incomplete information, which left only 17,818 useful data. In these 17,818 data, there were 749 genuine fire calls during this period; in that case only 17,069 (17,818 - 749 = 17,069) cases are available for this false alarm study.

1.1 Consequences of False Alarms

From the life safety point of view, false alarms not only risk the building occupants' safety, but also threaten the life safety of the fire brigade members. A fire alarm system that repeatedly gives false alarms produces mistrust in the building occupants, which in turn compromises fire safety awareness. When there is a genuine fire, they will have a slower response and cause a delay in evacuation. The false alarms also significantly affect available manpower for true emergencies. The false fire calls also incur safety concerns for the fire brigade crewmembers and public well being, because when appliances respond to emergency calls, they try to get to the incident at speed. This is likely to increase their risk of having the fire engine overturn or crashing with some other street users. Herschfield [2] mentioned, "From 1984 through 1993, 26 United States fire fighters died while responding to false calls, 11 of which resulted from alarm system malfunctions."

From the costing point of view, the false alarms not only affect the building owner, but also society. In the event of a false alarm, the occupants in the building would need to evacuate; if this happened in a commercial or manufacturing type of building, it would have an impact on the customers or the workers. The time spent by the brigade attending these fire alarm calls could be used for more essential duties, for example developing community fire safety and training. According to the HM Fire Service Inspectorate [3], a simple calculation for human resource hours lost in responding to false alarm can be calculated as follows: If a false fire call takes a minimum of 30 minutes to respond, and an average response of two appliances and 8 personnel, the total waste of human resource hours for the fire brigades because of attendance to false alarms in 1999/2000 was 97,584 hours. (24,396 false alarms x 8 personnel x 0.5 hours) The false alarms also impose financial burdens on fire authorities in relation to fuel costs, wear and tear on appliances and additional maintenance.

1.2 Literature Review

As stated in Section 1.1, false alarms are very costly events. Therefore, many studies have been conducted to reduce their occurrence. In United Kingdom, the

British Fire Protection Systems Association (BFPSA), the Chief and Assistant Chief Fire Officers' Association (CACFOA) and the Home Office joined in September 1997 to form a campaign aiming to reduce unwanted fire signals from automatic fire detection equipment. This joint Campaign makes it possible for all the partners to discuss industry related problems. This campaign requires fire brigades to continually identify the worst 20 sites in their area creating false alarms and then working with the management of those sites to put in place appropriate actions to reduce the false alarms [3].

Comparing the New Zealand statistics regarding the false alarms with the other countries reported by Killalea [4]:

> "62% of all false alarms in Tasmania (Australia) (from the 1996/97 fire data) are initiated by faulty Automatic Fire Detection Systems (AFDSs). Compared to the experience in other parts of the world, this figure is high. For example, in 1993 in the United States, the largest single cause of false alarms, at 41%, was automatic fire alarm systems (Alarm Association of Florida "False fire alarm position paper,"1998). The London (England) Fire Brigade have experienced similar results; in 1995 42% of false alarms were attributed to AFDS alarms not directly related to a real fire (Tilley, 1997)."

New Zealand Fire Service statistics [5] shows that 50.2% of the total false alarms they responded to came from fire alarm systems. This 50.2% is lower than the statistics in Tasmania, but higher than what they have in the United States and London. This might suggest that there is still some room for improvement in the false alarm situation in New Zealand.

Fry and Eveleight [6] reported false alarms given by automatic systems of all types in the United Kingdom in 1970 had a ratio of false calls to genuine fire calls of about 11:1. 10 years later, Gilbert and Taylor[1] did another study on the false fire calls in UK, and reported a much higher ratio of false calls to genuine fire calls of about 20:1 [7].

[1] This original document was not available, but this value was quoted by Donohue in his report [7].

In 1990, Donohue examined the false alarms in Hertfordshire for the fire calls received in 1985/1986. He reported:
"Analysis shows that environmental conditions account for 29% of false alarms received by Hertfordshire brigades. Various sources of smoke including tobacco smoke cause a further 15.3% of the false or spurious alarms. System faults account for 22% of all false calls and human intervention accounts for a further 21% of calls. It has also been found that the number of systems responsible for a given number of false alarms varies widely. For example, at the extremes of the range, 256 systems caused one false alarm and one system caused 165 false alarms."

1.3 Present New Zealand False Alarm Situation

From the emergency incident statistics (refer to Appendix 1), collected by the New Zealand Fire Service from 1995/96 – 99/2000, it shows that about 36% - 42% of the emergency calls they received were false alarms. The Fire Service was called through phone calls, private fire alarm calls, and other methods such as radio, running call direct to station and street fire alarms. This 36 to 42 percent of false alarm rate does not appear to be very high, but if we have a closer look at the fire calls that originate from private fire alarm calls, it shows that there will only be about 3 genuine fire calls for every 100 calls.

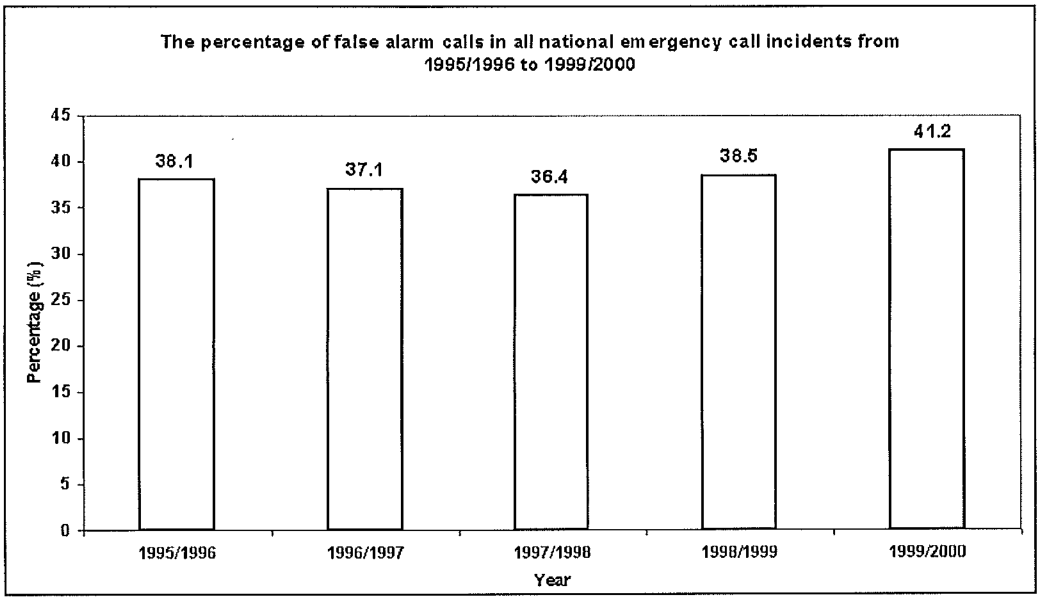


Figure. 1.1 The percentage of false alarm calls in all emergency call incidents throughout New Zealand for the period from 1995/1995 to 1999/2000.[2]

1.4 Objectives

The primary objectives of this report are:

1. To investigate the nature of false alarms by examination of the false fire calls data from private fire alarm (PFA) systems provided by AFA Monitoring Ltd. Any particular trends will be identified in order to try and develop recommendations to reduce the incidence of false alarms.
2. To develop a method to assist site engineers investigating false alarm occurrences by developing an expert system tool.

[2] Please refer to Appendix 2 Percentage of False Alarm Calculation for calculation of the false alarm percentage.

2.0 Operating Principles of Detection Systems

A fire can give off many products in different forms. Generally people would think that "fire products" mean material products such as gases or smoke particles, but fires also release energy through both convection and radiation. These fire products can be used for detecting fires.

2.1 Smoke Detector

Smoke is an 'aerosol', a suspension of liquid or solid particles in a gaseous medium. The smoke produced by a fire consists of a mixture of the combustion gases with the clean air drawn into the plume. The particles found in smokes vary in size from about one nanometre to ten micrometers in diameter.

There are three common types of smoke detecting devices:

1. Ionisation/light obscuration detector
2. Photoelectric/light scatter detector
3. Projected beam type detector

2.1.1 Ionisation Smoke Detector

This type of smoke detector is better at detecting the small smoke particles produced by flaming fires and it is commonly used because it is inexpensive. The operational principle of ionisation smoke detectors is to use an ionisation chamber which contains a source of ionising radiation. Inside the ionisation chamber, there is a small amount of americium – 241 and two plates with an electrical charge passing across them. The radioactive element americium has a half-life of 432 years, and is a good source of alpha particles. The alpha particles ionise the oxygen and nitrogen atoms of the air in the chamber. To "ionise" means to "knock an electron off." When an electron is knocked off of an atom, it ends up with a free electron (with a negative charge) and an atom missing one electron (with a positive charge). The negative electron is attracted to the plate with a positive voltage, while the positive atom is attracted to a plate with a negative voltage. The electronics in the smoke detector sense the small amount of electrical current that is generated by the movement of these electrons and ions moving toward the plates. When smoke enters the ionisation chamber, this current is disrupted – the smoke particles attach to the ions and neutralize them. The smoke detector senses the drop in current between the plates and sets off the alerting device.

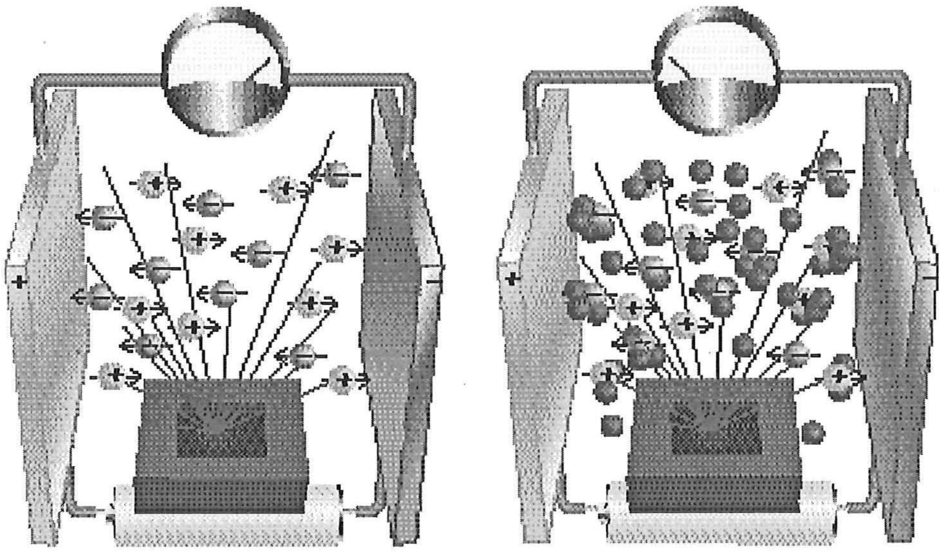


Figure 2.1 An ionisation detector operates by ionising air molecules with alpha particles from a radioactive material, americium 241. The ions then carry a small current between two electrodes (left). Smoke particles attach to the ions (right), thus reducing current flow and initiating an alarm [8].

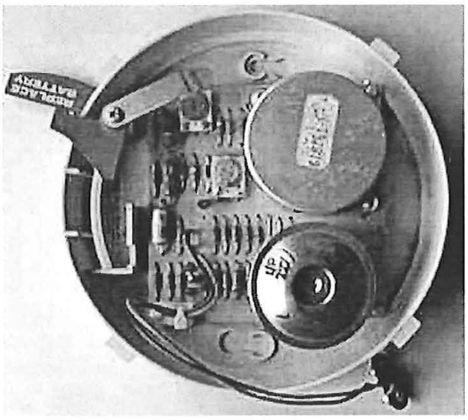


Figure 2.2 This is the inside look of an ionisation detector. It consists of three main parts: a printed circuit board, an ionisation chamber (the cylinder toward the top right in the adjacent picture), and an electronic horn (the brass cylinder toward the bottom right in the adjacent picture) as an alerting device [9].

Figure 2.3 The ionisation chamber is an aluminium can containing the ionisation source. The slots on it are to allow airflow. The can itself acts as negative plate of the ionisation chamber [9].

Figure 2.4 Underneath the can is a ceramic holder that contains the positive plate of the ionisation chamber. Under that plate is the ionisation source americium-241 [9].

The most common false alarm causes for this type of system are:

- Smoke and steam particles from cooking, shower or smokers
- Aerosol sprays – such as fly spray, air freshener, hairspray, paint, etc.
- Insect or dust entering the ionisation chamber
- Fumes from vehicles or heater
- Component failure – such as wiring error, panel failure, battery fault, etc.
- Dirty detector

2.1.2 Photoelectric/Light Scatter Smoke Detector

When smoke particles enter a light path, scattering results. Photoelectric detectors function by employing a light-emitting diode or a phototransistor that sends a beam of light unimpeded across a chamber. When smoke enters, light scatters in all directions. A photocell at an angle to the diode senses the light and sets off an alarm. The common false alarm causes for photoelectric smoke detector are very similar to the ionisation type, but it requires larger sized particles to activate.

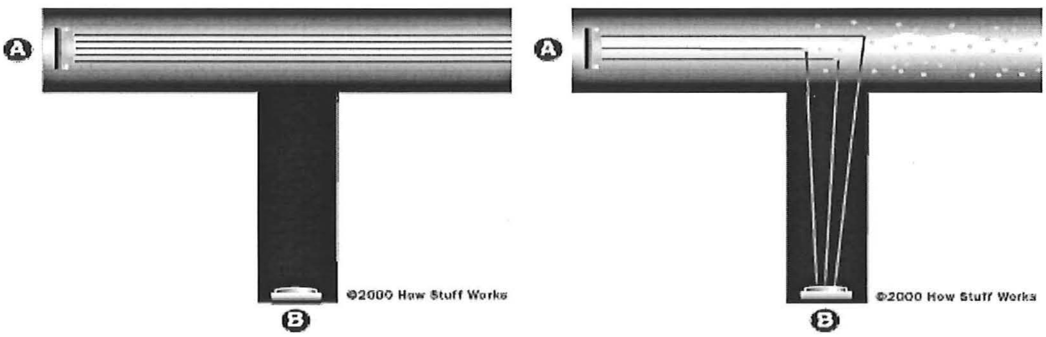


Figure 2.5 In the normal case, the light from the light source on the left shoots straight across and misses the sensor (left). When smoke enters the chamber, however, the smoke particles scatter the light and some amount of light hits the sensor (right); then the sensor sets off the horn in the smoke detector [10].

2.1.3 Projected Beam Type /Light Obscuration Smoke Detector

This type of smoke detector is used to protect large open areas. It generally consists of a light source at one end of the area to be protected and the photosensitive device at the other. When dense smoke obscures part of the light beam or less dense smoke obscures more of the beam, the light reaching the photosensitive device is reduced, and this initiates the alarm.

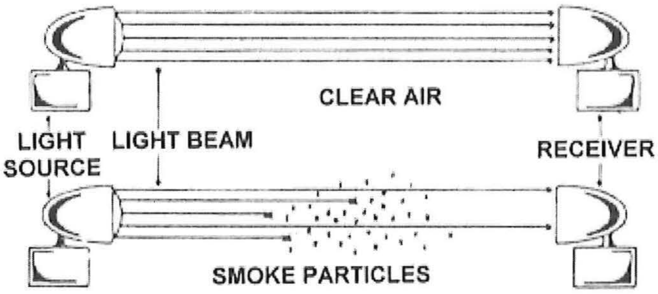


Figure 2.6 A projected beam smoke detector is a line-type smoke detector when smoke enters the light path and light is scattered or absorbed, thus reducing the intensity of light at the receiver. The sensing electronics respond to this reduction of intensity and initiate an alarm [11].

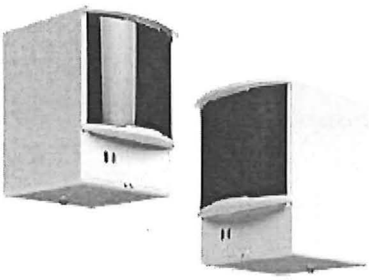


Figure 2.7 This is a picture of how the projected beam type smoke detector looks like. This picture was downloaded from a fire detectors catalogue [12].

The potential false alarm causes for a beam detector are [13]:

- Building movement – seismic or temperature effects may unalign mirrors.
- Mirrors may become dirty.
- The beam might be obscured by animals, people or machinery.
- The beam might be obscured by some non-fire event, eg. Steam, dust, etc.
- Response to other sources of light.

2.2 *Heat Detector*

Heat detectors are the oldest type of automatic fire detection device. Although the false alarm rate of heat detectors is the lowest among all automatic fire detection devices, they also are the slowest in detecting fires. Heat detectors respond to heated air that has risen by convection to the detector location. The thermal energy from a fire can be used to melt fusible elements, to bend bimetallic strips, or to expand gases; any of these can be used to make or break electrical contacts or release mechanical triggers to raise the alarm.

There are many possible sub-divisions of heat detectors, but one of the most important divisions is between point-type and line-type heat detectors. Burry [14] defined a typical point detector as a detector which is intended to be smaller than the area affected by the fire, so that the detector can be expected to be heated by the fire across all its surface simultaneously. If, however, the intention is that the detector gives an alarm signal while only part of its length is exposed to the fire, then it should be considered as a line detector.

2.2.1 Point Type Heat Detector

The point type heat detector can be further subdivided into the two categories: fixed temperature detectors and rate-of-rise detectors. The term fixed temperature detector means these detectors will operate when their sensing elements reach specified temperatures, regardless of the rate of rise of the raised air temperature. The operational principle of a ‘rate-of-rise’ heat detector uses the rapidly increase in air temperature in the space above a flaming fire. It will function when the rate of temperature increase exceeds a predetermined value. It is designed to compensate for the normal changes in ambient temperature that are expected under non-fire conditions.

Fixed-Temperature Heat Detectors

The fixed-temperature heat detectors can be further divided into the two categories according to their operating principles. They are fusible-element type and bimetallic type. The fusible-element type uses a eutectic metal to actuate an electrical heat detector. The eutectic metal is often used as a solder to secure a spring under tension. When the element fuses, the spring acting closes contacts and initiates an alarm. Devices using eutectic metals cannot be restored.

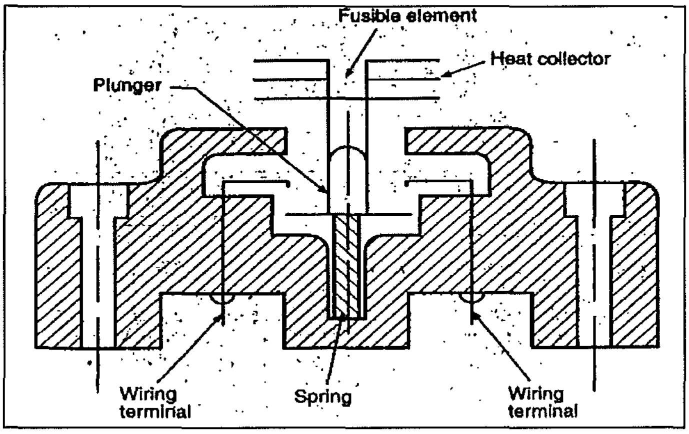


Figure 2.8 A fixed-temperature heat detector, spot-type, with fusible element [15]

The bimetallic type heat detector uses differential expansion between two metals with unlike thermal expansion coefficients. This device consists of two metals with different coefficients of thermal expansion bonded together, when this apparatus is heated, the bonded metals will be bended toward the one with lower expansion rate. A normally open circuit will be closed and activate the alerting device due to this variation in metal expansion.

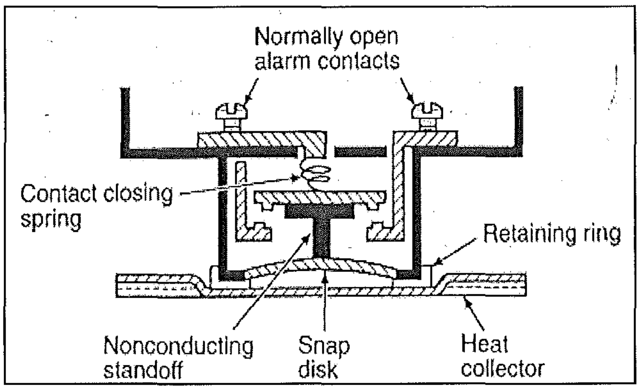


Figure 2.9 A spot-type fixed-temperature, bimetallic snap disc type detector [15]

Rate-of-Rise Heat Detectors

Burry [16] mentions the two major disadvantages of a fixed-temperature heat detector.

> "Fixed-temperature detectors have two major problems. firstly, the operating point is delayed in fast-growing fires, just when the most rapid detection is required. Secondly, the size of fire required to operate a fixed-temperature detector varies with the ambient temperature."

The rate-of-rise heat detectors were originally produced in order to solve the problems that a fixed-temperature detector has. There are two typical constructions of rate-of-rise detectors; they are bimetal rate-of-rise detector, and pneumatic detector. Burry [16] explains more detail on how these two types of devices work as follow.

Figure 2.10 is an example of using bimetal strips to sense the air temperature. Each of these strips consists of two layers of metal having differing rate of expansion with temperature; as the temperature increases the expansion will cause the combined strip to bend. Figure 2.10a shows two such strips, nominally identical except that the upper one is lagged, mounted close together with one end of each strip rigidly connected to the detector base while the other ends carry a pair of electrical contacts. For slow changes in air temperature both strips will have sufficient time to heat or cool, the lagging on the upper strip having little effect. For fast changes in temperature the lagging will prevent the temperature of the upper strip from changing, and hence the upper contact will not move; the lower strip being unlagged will be able to respond and an increase in temperature will cause its contact to rise until it meets that of the upper strip (Figure 2.10b).

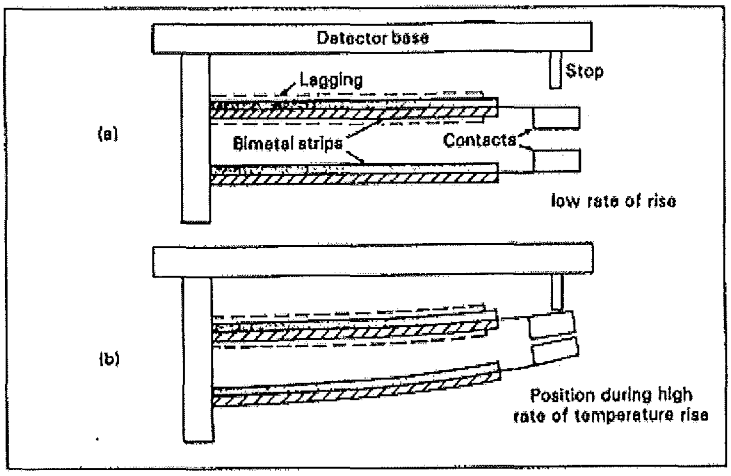


Figure 2.10 Bimental rate-of-rise detector. [16]

The device shown in Figure2.11 uses a hemispherical air chamber formed by a thin metal shell and a thin flexible diaphragm. The diaphragm carries a contact which can make with a second contact rigidly fixed to the detector's body. At the bottom of the shell there is a very small bleed hole. For slow changes of temperature the bleed hole is large enough to allow equalisation of the pressures inside and outside the shell. As the rate of rise of temperature increases, however, the bleed hole becomes unable to pass the expanded air sufficiently quickly and the diaphragm will rise until the contacts meet.

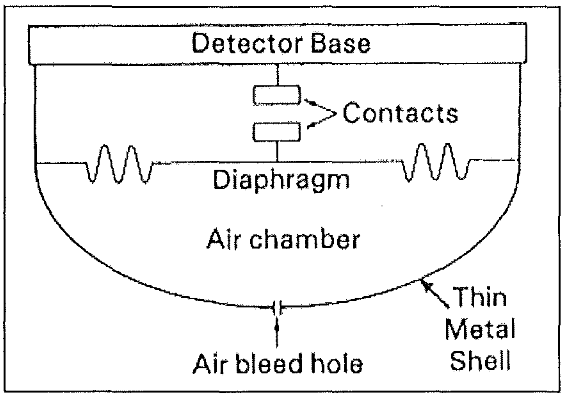


Figure 2.11 Pneumatic rate-of-rise detector. [16]

2.2.2 Line Type Heat Detector

The major distinction between different line types of heat detectors is whether the detector is integrating type of system or not. Burry [16] defines an integrating detector as a line type heat detector looks at the average temperature over its length while the non-integrating system looks only at a portion of the detector.

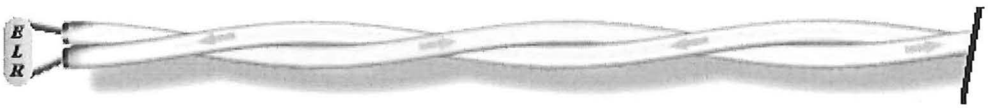
Integrating Line Detector

Burry [16] gives an example of the integrating detector. A length of tube, filled with gas and terminating in a pressure switch, in a fire the air in the tube will try to expand, increasing its pressure until the pressure switch operates and gives the alarm. The increase in temperature required to operate the switch will not always be the same, however. If all the tube is heated simultaneously, it may only require a temperature increase of 10°C, if only half the tube is heated then it might require an increase of 20°C over that half, if a quarter of the tube is heated then an increase of 40°C over that quarter, and so on with the increase needed getting bigger as the length heated gets smaller.

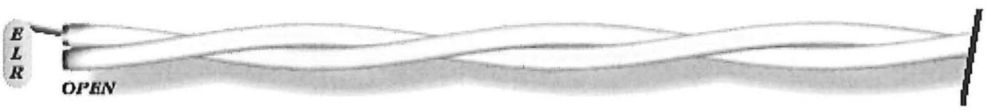
Non-Integrating Line Detector

An example of a non-integrating detector, consider two springy steel wires, each insulated by a low melting point plastic coating, twisted together so that if the insulating plastic melts the wires will spring together and make contact. In this design the operation depends on some part of the plastic melting; until the melting point is reached at some point along the wires no alarm can be given [16].

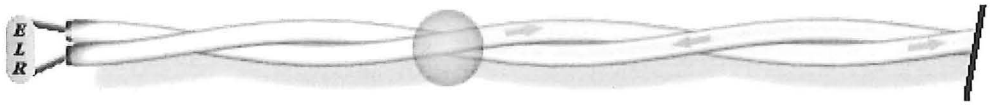
The following diagrams show an example about how a non-integrating line detector works.



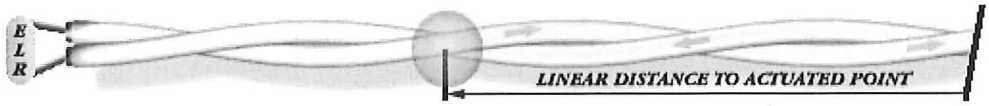
1. Supervision - The entire length of this line heat detector is supervised by a conventional initiating device circuit. A small current is continuously passed through the detector and end of line resistor (ELR). The end line resistor limits the amount of current to a preset level which the monitoring circuit is configured to treat as a normal condition. [17]



2. Fault conditions - If an open circuit condition occurs anywhere in the loop, current is no longer allowed to flow through the line detector. The monitoring circuit is configured to treat this as a fault or trouble condition. [17]



3. Alarm Conditions - If a portion of this detector is exposed to heat above its rated alarm temperature the heat sensitive polymer breaks down and a short circuit occurs at that point. This bypasses the end line resistor greatly increasing the current flow through the loop. The monitoring circuit is configured to treat this as an alarm condition. [17]



4. Alarm Point Location – With a specially designed control panel, it is possible to locate the alarm point by measuring linear distance representing the length of line detector from where this line detector starts to the actuated point can be displayed at the control panel. [17]

Heat detectors do not give many false alarms due to Environmental Effects, except for the hot air from cooking and shower, in stead the Component Failure is the most likely cause of false alarms for this system type. The corrosion of a heat detector system will reduce the reliability of this system; water leaks into the system will also cause a false alarm. Wiring and panel faults are also very common reasons for causing nuisance alarms.

2.3 *Automatic Sprinkler Systems*

Solomon [18] defines a sprinkler as a device that is designed to discharge water over a certain area, is only activated when a fire generates a sufficient quantity of heat, and will control or suppress the fire once it has activated. There are four basic types of sprinkler systems: (1) wet pipe, (2) dry pipe, (3) preaction, and (4) deluge systems. Solomon gives more details about each of these four systems as follow.

2.3.1 Wet Pipe System

This system contains water under pressure at all times and utilizes a series of closed sprinklers. Once a fire occurs and produces enough heat to operate one or more sprinklers, the water will discharge immediately from any of the open sprinklers. This is the first choice of designers and installers, and should only be used when the temperature of the protected area is maintained at or above 4°C.

2.3.2 Dry Pipe System

These systems are found in environments where the temperature is maintained below 4°C. The system contains air under pressure under normal circumstances. A dry pipe valve is used to hold back the water. When a fire occurs and enough heat is generated, one or more sprinklers will operate, the system air pressure will then escape through the open sprinklers, drop to a predetermined level, and allow the dry pipe valve to open. Once the valve opens, the water supply will be admitted into the system piping, fill the pipe network, and discharge from any sprinklers that have operated.

2.3.3 Preaction System

This system is typically provided with some minimal quantity of air pressure, thus the pipe network has no water in it under normal circumstances. The water supply is held back by means of a preaction valve. This preaction valve is controlled by a supplemental detection system. Operation of this supplemental detection system allows the preaction valve to automatically open and admit water into the pipe network. Water will only be discharged until the fire produces sufficient amount of heat to operate the sprinkler(s). This system type is typically found in place with computer equipment or communication equipment, museums, and other facilities where inadvertent water discharge is of major concern to the end user.

2.3.4 Deluge System

A deluge system delivers large quantities of water over a large area in a relatively short period of time. This type of system consists of three basic elements, open sprinklers, a deluge valve, and a supplemental detection system. The sprinklers that are used in a deluge system have their operating elements removed, and this system pipe is at atmospheric pressure, since the open sprinklers are attached to it. A deluge valve is used to control the system water supply. The supplemental detection system is the key to operate this deluge system. Upon activation of this supplement detection system the deluge valve is electrically opened, thereby admitting water into the pipe network. As the water reaches each sprinkler in the system, it immediately discharges from the open sprinkler.

The most common causes of sprinkler system false alarms are [19]:

- Main pressure rises to a level that is greater than installation pressure which allows main valve to lift and generates a call.
- Water leaks in a wet sprinkler system or air leaks in a dry sprinkler system can cause a fall in installation pressure, which allows mains pressure to lift main valve and produces a call to the Brigade. A fall in pressure may allow pumps to cut in, causing main valve to lift generating a call.
- Mechanical damage of the system caused by some external forces, such as building works, forklift movements, etc.

This following table shows the characteristics of common detector types.

Detector Type	**Suitable for**	**Not suitable for**	**Susceptible to**
Heat detector (fixed and rate of rise)	General use Utility areas High humidity environments Dirty or smoke environments	Sleeping areas Egress routes High ceilings Smouldering fires High value risks	Vibration Corrosion/water Physical damage
Ionisation smoke	General use Open flaming fires	Slow smouldering fires Ductwork Vehicle parks	Wind gusts Cooking fumes, dust Vehicle exhaust Insects Dust and dirt Tobacco smoke
Optical smoke	General use Dense visible smoke Electrical cable fires Areas with high air flows	Clean flaming fires	Vibration Building movement Strong light sources Thermal turbulence Dirt and insects Condensation
Linear Beam Optical detectors	High atria Limited access areas Heritage ceilings	Small fires Clean burning fires Slow smouldering fires	Vehicle exhausts Heavy tobacco smoke
Gas detection	Smouldering fires False alarm minimisation	Rapid flaming fires High humidity/temperature	

Table 2.1 Characteristics of common detector types [20].

3.0 Expert Systems

Jackson [21] defines an expert system as a computing system that is capable of representing and reasoning about some knowledge-rich domain, such as internal medicine or geology, with a view to solving problems and giving advice. It deals with subject matter of realistic complexity that normally requires a considerable amount of human expertise; it must exhibit high performance in terms of speed and reliability in order to be a useful tool; and it must be capable of explaining and justifying solutions and recommendations in order to convince the user that its reasoning is, in fact, correct.

In this report, the particular expert system software used is Expert System Builder Version 4.0 (ESB), which is a program intended to simplify the development of practical fuzzy decision support systems (or expert systems) that can be used in the day-to-day decision making processes of most organisations. This program can be downloaded from Internet at the website addressed http://www.esbuilder.com/downloads.htm.

A flowchart for using the Expert System Builder is drawn below:

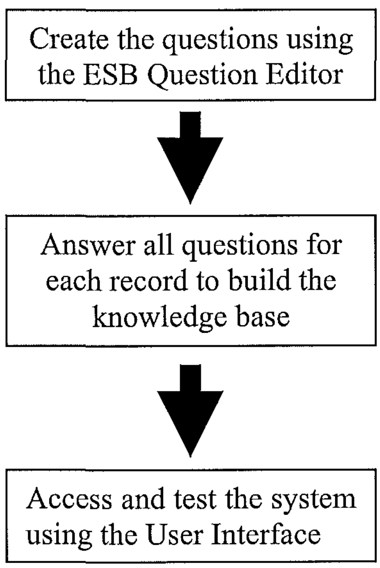


Figure 3.1 This is a flowchart showing the process of developing the Expert System Builder.

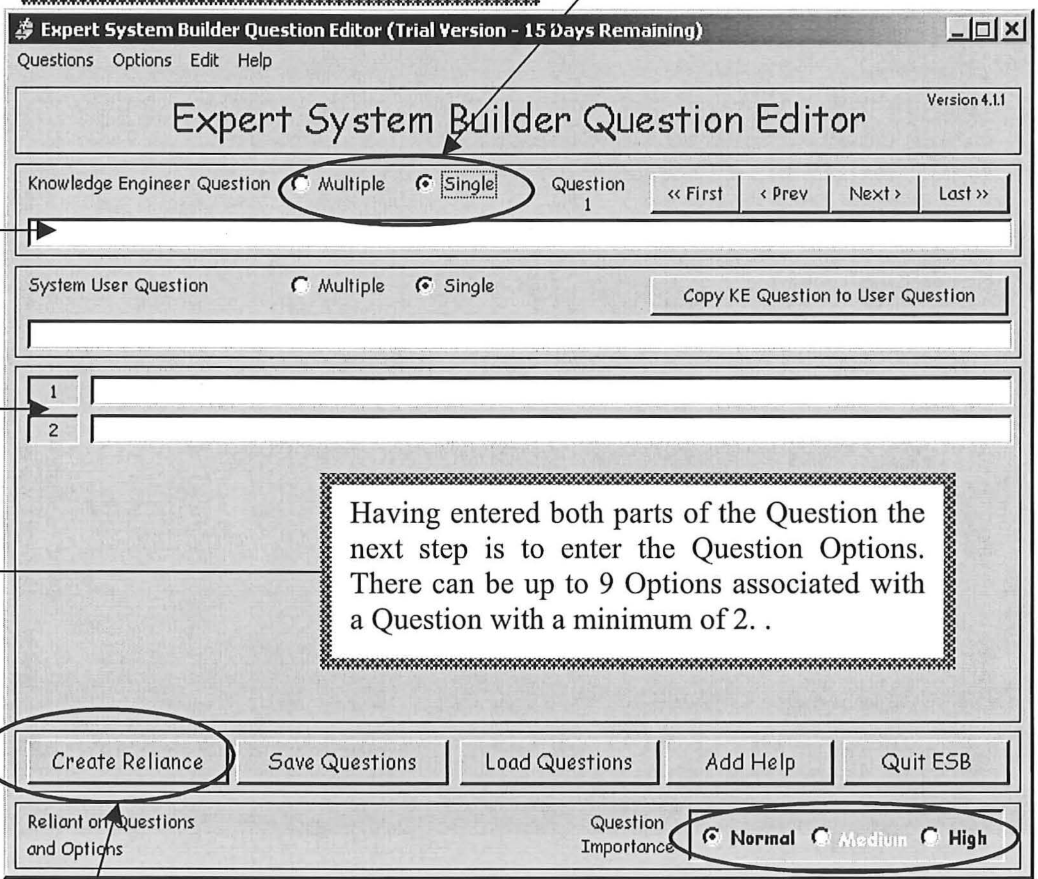
3.1 ESB Question Editor

The ESB user help file states that there are three programs that comprise the Expert System Builder (ESB) series of programs. Together these allow non-programmers to develop their own expert (or knowledge based) computer system, that is to say a computer system that can give advice on a particular subject in the same way as a human expert would. The first program is called the ESB Question Editor. The ESB Question Editor is the program used to start developing the system. It is used to build a bank of questions, and the series of associated responses, upon which the complete system is developed. The questions developed here form the backbone of the complete system. Dependencies between questions are set-up such that one question is only asked if the responses given previously deem so. Questions are assigned an importance so that key questions have a greater effect on the final outcome.

In the Question Editor, the question can be set to have either multiple or single answer. If a question has a multiple type answer, the user can answer "No", "Unlikely", "Neutral", "Perhaps" and "Yes". But if the question was specified to have a single type of answer, the user can only pick on the option rather than giving each option a score as they can in the multiple type answer. The Question Editor can have the maximum number of nine options for each question and it is also possible to set the reliance between different questions.

ESB Question Editor sets the structure and content of the Questions upon which the Expert System is developed. The options for each Question remain the same for both the System User and the Knowledge Engineer, however the wording for the questions does not need to be the same. The question entered here, will show up on the screen in Knowledge Acquisition program, which is the question to the Knowledge Engineer. The question entered in the System User Question box will appear to the program end users.

These boxes enable the Question Designer to determine how both the Knowledge Engineer and System User can respond to Questions. the multiple answers type question allows a range of values to be entered for a particular Question Option whereas a single answer question only allows the selection of one particular option.



Having entered both parts of the Question the next step is to enter the Question Options. There can be up to 9 Options associated with a Question with a minimum of 2. .

It is possible to create reliance between this question and other questions by simply clicking on this button to set up the dependence.

The Importance of each Question is obviously different. It is possible with ESB Question Editor to set the level of each Question in respect to other Questions using these boxes. Note that not all Questions can be High or Medium.

Figure 3.2 Illustration of the Question Editor program.

3.2 Knowledge Acquisition Program

The second in the series the Knowledge Acquisition program is used to populate the knowledge base of the system. The Knowledge Acquisition help file describes how a system developer (aided perhaps by a domain expert) enters records into the system and assigns a weighting to each of the options associated with each question in the system for the new record. That is to say some options on a particular question will add to the probability of the record being the correct answer whilst other will detract from it. These weightings are then used by the User Interface program, together with the users actual responses, to determine which records to recommend.

The Knowledge Base (KB) of the system is a very important part since without it the system will be unable to work. Creating the KB consists of answering each of the Questions in the Question File for each of the records entered. This process relies heavily on the designer as they have to take into account ideal answers, possible answers and answers that definitely disprove a particular record.

After entering the name of a new record, the knowledge engineer can start to answer each question either by using the slide bars or option boxes depending on what answer type was chosen in Question Editor.

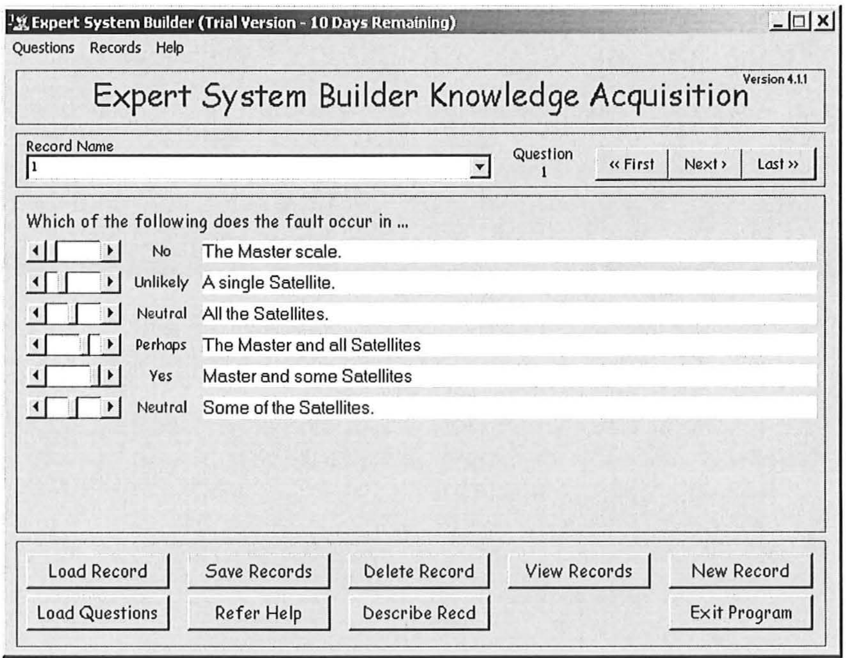


Figure 3.3 This above diagram shows an example of a multiple answer type question.

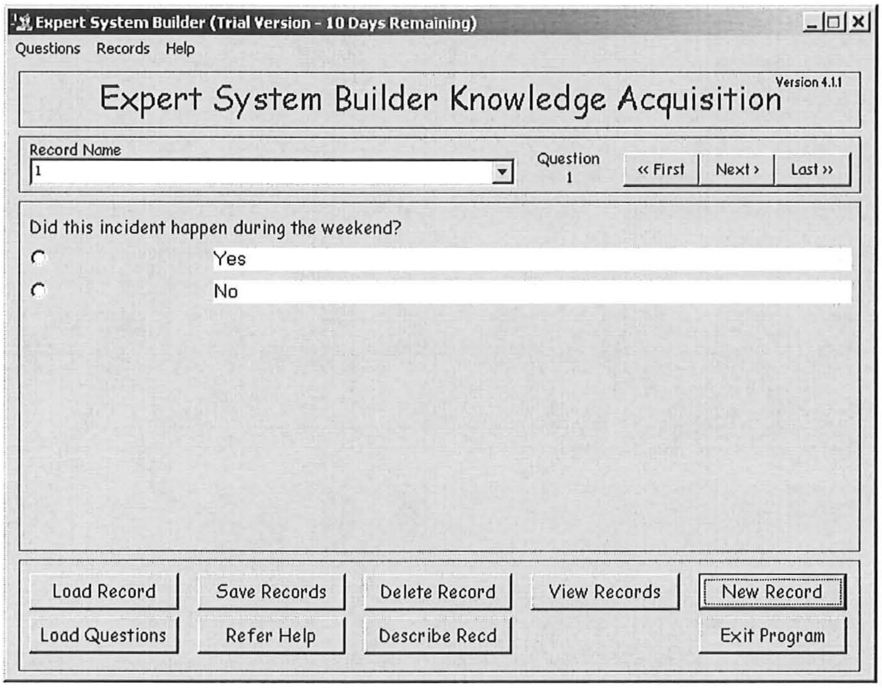


Figure 3.4 This above diagram shows an example of a single answer type question.

3.3 ESB User Interface Program

The User Interface collates all of the information entered in the above two programs and presents the user with a set of questions to answer. Using the user inputs, the knowledge base of information entered with the knowledge acquisition program and its own inference engine the system uses 'fuzzy logic' to determine the record(s) that best suit the data entered by the user. This is presented as an ordered table with the most likely solution at the top.

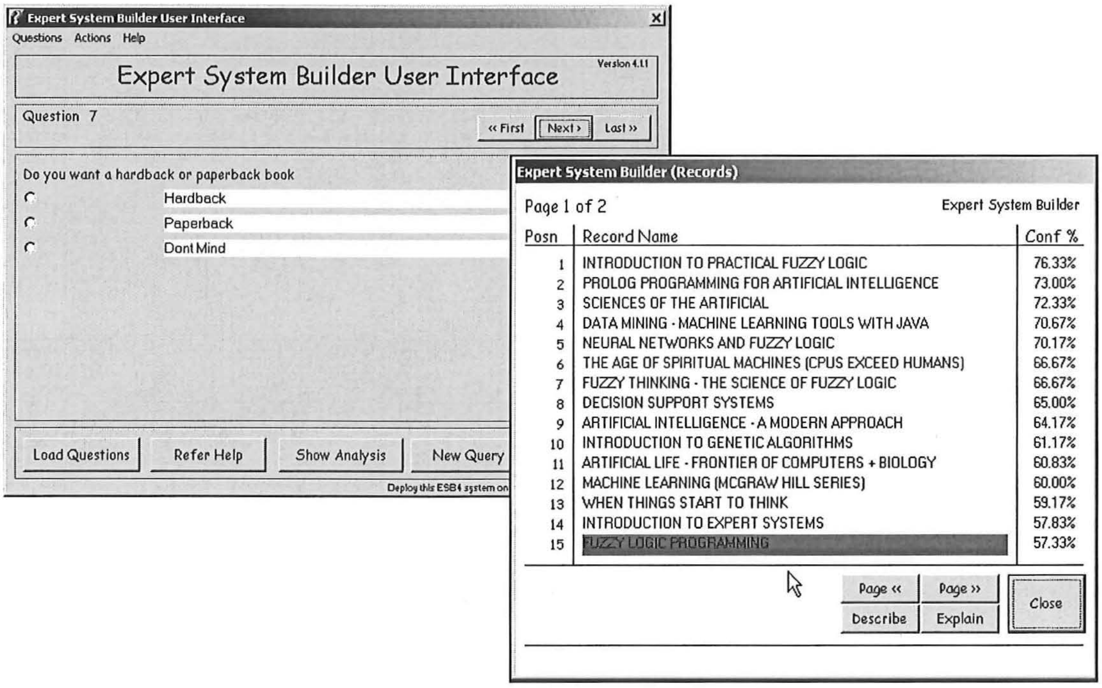


Figure 3.5 After answering all the questions in the Expert System Builder User Interface, the analysis result can be seen by either click the "Next" button or the "Show Analysis" button. To commence a new query, simply click on the "New Query" button to start over again.

4.0 Clues for Identifying Causes of False Alarms

From the AFA database, the causes of false alarms can be categorised into the following nine groups.

Reason	Symbol	Subset of the reason
Building Work – Builders/Subcontractors	B	Builders, Concrete Cutters, Flooring Specialists, Painters Electricians, Data Technician, Lift Engineer, Plumbers, Waterblasters, Air Conditioners/Refrigeration Engineer, Cleaners, Other
Component Failures	C	Heat Detectors, Smoke Detectors, Manual Call Point (MCP), Sprinkler Pipe, Sprinkler Head, Sprinkler Valve, Panel Fault, Direct Brigade Alarm (DBA) Fault, Wiring, Battery, Water Leak, Transmitter, Lightning, End of Line (EOL), Anti-Interference Switch, Other
Environmental Effects	E	Cooking, Toaster, Steam from Showers and Cooking, Smokers, Smoke Machine, Insects, Dust, Vehicle Fumes, Fluctuating Water Pressure, Hairsprays/Flysprays, Candles/Incense, Heater Fumes, Water Leak, Other
Good Intent	G	
Incorrect Building Maintenance	IB	Dirty Smoke Detector, Heater Dusty, Water Leak, Leaking Roof, No Call Point Glass, Other
Installation Fault	IF	Heat Detector with Low Tolerance Temperature Limit, Improper Selection of Smoke Detector, Improper Installation, Different Detector, DBA Fault, Other
Malicious	Ma	
Mechanical Damage	Me	Forklift, Truck, Other
Operator Error	O	Agent, Owner, Other

Table 4.1 The nine groups of false alarms causes

For the above nine categories of reasons, one major assumption was made that if the fire call happened in a building with construction work or renovation going on, then the only reason for the false alarm call would be the Building Work (B) construction. This is because of the lack of information, as there is no statistics showing how many false alarms were caused by other reasons on a construction site. This assumption should not be too far out from reality because on a construction site, it should have restricted public access; therefore that would limit the possibility of malicious and operator error types of false alarms. If there is any mechanical damage to the system, it is most likely to be caused by the Building Work (B) on the construction site. It is not likely that there are cooking activities on the construction site; therefore, the Environmental Effect (E) should not be a concern. But for a renovation building work, the facility may still be occupied. Therefore this assumption may affect the accuracy of this analysis.

In order to assist the site engineers to find the reason for a false alarm, the author used the provided data to analyse the regional and seasonal effects. The author also looked at how the different AFD system types and building types affect the reason for false alarms and if the different time period during a day, and the state of occupancy in the building have any effect on the reason for a false alarm. The results for the above factors are shown in the pie charts in the following subsections.

The first set of questions that the author believed would be useful to identify the cause of a false alarm is:

- Where was the location of this fire call?
- What time was it? (Cooking hour or not?)
- What season was it?
- Was this building occupied?
- What type of building is it?
- When was the last maintenance for the detection system?
- Was there any construction work going on?
- What type of detection system was it?
- When was the automatic fire detection (AFD) system installed?

In the following section, these questions have been studied in more detail.

4.1 Regional Effect

The different climatic conditions and insect species in different geographical locations may have some kind of effect on the performance of a fire detection system. The different economic activities in the different regions may have some influence on the occurrence of false alarms, therefore when a fire call is received; the very first question that can be asked is "Where was it?"

4.1.1 Dividing the Fire Regions

There are many different ways to divide the regions in New Zealand; in this report, the regions are divided into the eight fire regions which are the same fire regions as the New Zealand Fire Service divisions. They are Northland, Auckland, Bay-Waikato, Arapawa, Transalpine, Southern, Eastern, and Western fire regions as shown in Figure 4.1. Appendix 3 shows fire stations covered in each region.

Figure 4.1 The New Zealand fire region map from New Zealand Fire Service

4.1.2 Results for Regional Effect Study

	Northland	Auckland	Bay-Waikato	Arapawa	Transalpine	Southern	Eastern	Western
Building Work/Subcontractors	63	1183	277	579	433	219	83	106
Component Failure	192	1563	492	684	597	344	221	214
Environmental Effects	153	1618	398	583	524	248	223	222
Good Intent	10	294	57	240	158	39	39	28
Incorrect Building Maintenance	31	443	141	177	154	97	41	56
Installation Fault	4	127	27	47	61	18	23	15
Malicious	37	623	148	332	217	101	57	90
Mechanical Damage	10	324	79	121	98	42	39	35
Operator Error	14	425	131	183	195	99	64	59

Table 4.2 This table summarised the frequency of different reasons for causing false alarm in the eight regions.

4.1.3 Discussion for Regional Effect

The different reasons for the occurrence of false alarms in these eight regions are ranked according to percentage. Rank 1 has the highest percentage score, then rank 2 and so on. The highlighted columns are the reasons for false alarms; refer to Table 4.1 for the meanings of the listed symbols.

Rank	Northland		Auckland		Bay-Waikato		Arapawa	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	C	37	E	25	C	28	C	23
2	E	30	C	24	E	23	B E	20 20
3	B	12	B	18	B	16	-	-
4	Ma	7	Ma	9	Ma IB	8 8	Ma	11
5	IB	6	IB	7	-	-	G	8
6	O	3	O	6	O	7	IB O	6 6
7	G Me	2 2	Me	5	Me	5	-	-
8	-	-	G	4	G	3	Me	4
9	IF	1	IF	2	IF	2	IF	2

Rank	Transalpine		Southern		Eastern		Western	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	C	24	C	30	C E	28 28	E	27
2	E	22	E	21	-	-	C	26
3	B	18	B	18	B	11	B	13
4	Ma	9	IB Ma O	8 8 8	O	8	Ma	11
5	O	8	-	-	Ma	7	IB O	7 7
6	G IB	6 6	-	-	G IB Me	5 5 5	-	-
7	-	-	G Me	3 3	-	-	Me	4
8	Me	4	-	-	-	-	G	3
9	IF	3	IF	1	IF	3	IF	2

Table 4.3 These two tables show the ranks of the different causes of false alarm in the eight regions.

The above table shows that the top two reasons for causing false alarms in all eight regions are Component Failure (C) and Environmental Effect (E). The Building Work (B) is the third on the row, but it has a much lower percentage than the top two reasons. The following four reasons, Malicious (Ma), Mechanical Damage (Me), Incorrect Building Mainenance (IB) and Good Intent (G), have very similar scores. Installation Fault (IF) is always the least likely reason for causing false alarm in all regions; in one hundred false fire calls, only two or three cases are likely to be caused by Installation Fault (IF). The location only has a very minor effect on the occurrence of a false alarm; therefore, this question may be removed from the question list.

4.2 Occupant Activity Effect

These questions were asked to analyse how the occupant activities would cause the false alarms, "Was it the weekend?" and "What time of a day was it?"

4.2.1 Dividing the Time of a Day

A day was divided into 5 different stages: Breakfast, Lunch, Dinner, Office Hours (non-cooking day-time hours), and Night-Time (bedtime). During Breakfast time, the toaster is a potential source for causing a smoke detector to activate and give a false alarm. Also during the Breakfast hours, people are also likely to be in the shower; therefore, a false alarm could be raised because of the steam from the shower. Cooking and BBQ are likely to give the unwanted fire signal during Lunch time, and Dinner time. During the Night-Time, because many of the buildings would be expected to be unoccupied, false alarms happen at this stage should have different most likely cause from the other times during a day.

Stage	Hours
Breakfast	06:00 ~ 09:00
Lunch	11:00 ~ 14:00
Dinner	17:00 ~ 21:00
Office Hours	09:00 ~ 11:00 & 14:00 ~ 17:00
Night-time	21:00 ~ 06:00

Table 4.4 This table shows the hours (in 24-hour system) for each stage.

4.2.2 Results for Occupant Activities Effect Study (Time of a day)

	Breakfast	Lunch	Dinner	Office Hour	Night Time
Building Work/Subcontractors	333	842	276	1334	159
Component Failure	594	736	657	1230	1090
Environmental Effects	726	656	826	950	811
Good Intent	108	163	147	277	170
Incorrect Building Maintenance	144	154	220	295	327
Installation Fault	43	66	58	110	44
Malicious	69	250	322	390	575
Mechanical Damage	83	171	125	257	112
Operator Error	143	333	101	509	83

Table 4.5 This table summarised the frequency of different reasons for causing false alarm at the five different time stages.

4.2.3 Discussion for Occupant Activities Effect (Time of a Day)

Rank	Breakfast		Lunch		Dinner		Office Hours		Night-time	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	E	32	B	25	E	30	B	25	C	32
2	C	26	C	22	C	24	C	23	E	24
3	B	15	E	19	Ma	12	E	18	Ma	17
4	IB O	6 6	O	10	B	10	O	10	IB	10
5	-	-	Ma	7	IB	8	Ma	7	B G	5 5
6	G	5	G IB Me	5 5 5	G Me	5 5	IB	6	-	-
7	Me	4	-	-	-	-	G Me	5 5	Me	3
8	Ma	3	-	-	O	4	-	-	O	2
9	IF	2	IF	2	IF	2	IF	2	IF	1

Table 4.6 This table shows the ranks of these different reasons for causing false alarms at different time stage according to the percentage score.

The above table suggests that during Breakfast and Dinner time because of the cooking activities in the buildings, a false alarm has about a 30% chance to be caused by Environmental Effect (E). The Environmental Effect (E) during Lunch time does not seem to have as much effect as it has during Breakfast and Dinner time. The author believed that is because most people have a packed lunch instead of cooking during that time; therefore the Environmental Effect (E) may not be ranked as high as the other two meal periods.

Table 4.6 also shows that the possibility of having a Component Failure (C) type false alarm is around 24%, except at Night-Time. At Night-Time, it is most likely to have a Component Failure (C) type false alarm (32%). This could be because of the fact that the majority building occupants are asleep, therefore a false alarm is less likely to be caused by human activity.

Malicious (M) type of false alarm is of more concern (over 10%) during the Dinner and Night-Time. This may be caused because of during the Dinner and Night-Time, there are fewer people in a commercial building, and that makes it easier for those people who maliciously set off the alarm. The Operator Error (O) during these two time stages is much lower than other time frames, which is reasonable because the operators are not likely to work during this time.

Building Work (B) is the top ranked reason for causing the false alarm in Lunch time and Office Hours. This is expected because the builders and subcontractors are working during these time frames.

The Good Intent (G), Mechanical Damage (Me), Incorrect Building Maintenance (IB) and Installation Fault (IF) types of false alarms have very similar percentage scores (about 5%) at all times.

From this study, the occupant activities do have some effect on the causes of false alarms. Therefore, it is a good idea to keep the question, "What time was it?" in the question set.

4.2.4 Dividing a Week into Weekdays and Weekends

During the weekdays students need to attend school and employees need to work, therefore, it was expected that the human activities might be different between weekdays and weekend.

Although it is arguable whether Friday night should be counted as weekend, because the time effect has been accounted in Section 4.2.1, to avoid double counting the weight of Friday night; Friday is kept under the category of weekday.

4.2.5 Results for Occupant Activities Effect Study (Day of a week)

	Weekend		Weekday	
	Frequency	# of FA / day	Frequency	# of FA / day
Building Work/Subcontractors	381	1.82	2563	4.91
Component Failure	1013	4.85	3294	6.31
Environmental Effects	1088	5.21	2881	5.52
Good Intent	200	0.96	665	1.27
Incorrect Building Maintenance	276	1.32	864	1.66
Installation Fault	66	0.32	256	0.49
Malicious	574	2.75	1031	1.98
Mechanical Damage	130	0.62	618	1.18
Operator Error	128	0.61	1041	1.99

Table 4.7 This table shows the frequency of different reasons for false alarms during weekdays and weekend.

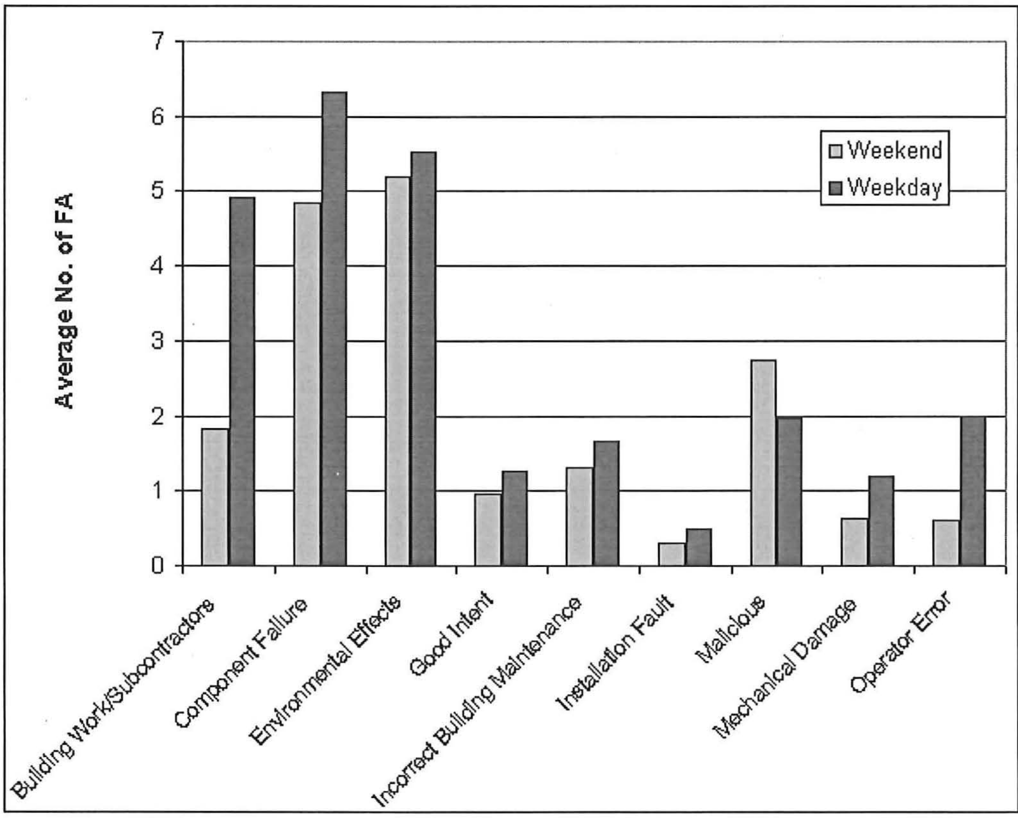


Figure 4.2 This above figure shows the average number of false alarms in weekend and weekday and categorised them into different reason groups.

4.2.6 Discussion for Occupant Activities Effect (Day of a week)

Rank	Weekday		Weekend	
	Symbol	%	Symbol	%
1	C	24	E	29
2	E	22	C	26
3	B	19	Ma	15
4	Ma O	8 8	B	10
5	-	-	IB	7
6	IB	7	G	5
7	G Me	5 5	Me O	3 3
8	-	-	-	-
9	IF	2	IF	2

Table 4.8 This table shows the ranks of these different reasons for causing false alarms during weekdays and weekend according to the percentage score.

Table 4.8 shows that the top reason for false alarms is either Component Failure (C) or Environmental Effect (E). The percentage differences between these two reasons are very small for both weekday and weekend (about 2% or 3%).

The third highest ranks for weekday and weekend are very different; during the week, the Building Work (B) is more likely to cause the false alarm while during the weekend Malicious (Ma) fire calls seem to be of more concern. During the week, the false alarms caused by Building Work (B) are about 20% of all the false fire calls. This is almost double what it is during a weekend. This is reasonable because during the weekend, the contractors and subcontractors should also have their days off; therefore there is less likely to be construction work during the weekend. The Malicious (Ma) type false alarm in a weekend has a percentage of 15%, which is almost double what it is during week time, 8%. This might suggest that when people are away from work, there is a higher chance of getting Malicious (Ma) type of false alarms.

During the week time, the Operator Error (O) type of false alarms is almost triple what it is during the weekend. This could be due to the fact that the operators (agents, and building owners) do not work on weekends. The Mechanical Damage (Me) during the weekend is also lower than during the week time. This is because there is a very high proportion of Mechanical Damage (Me) caused by forklifts and trucks in the industrial facilities; it is expected these places would have less occupant activities during the weekend than week time.

For the other types of false alarms, Good Intent (G), Incorrect Building Maintenance (IB) and Installation Fault (IF), they have similar possibilities of occurrence during the week and weekend.

4.3 Seasonal Effect

The climatic conditions may vary from season to season. The maximum temperature may be higher in summer, and has the potential to cause false alarm in a heat detection system. During springtime, there is a higher amount of pollen floating in the air, and it may cause the smoke detection system to give some untrue fire signals. The humidity may also be a problem causing Component Failure (C). All these seasonal effects may show a difference on the trend of false alarm occurrences. Therefore, the author decided to look at the seasonal effect.

4.3.1 Dividing the four seasons in a year

New Zealand is a country with four seasons. The author divided a year into four seasons.

Spring	September, October, and November
Summer	December, January, and February
Autumn	March, April, and May
Winter	June, July, and August

Table 4.9 This above table shows the months in each season.

4.3.2 Results for Seasonal Effect

	Spring	Summer	Autumn	Winter
Building Work/Subcontractors	746	716	678	804
Component Failure	1065	1118	982	1142
Environmental Effects	928	910	983	1148
Good Intent	251	194	155	265
Incorrect Building Maintenance	247	308	305	280
Installation Fault	64	107	77	74
Malicious	464	312	383	446
Mechanical Damage	195	174	183	196
Operator Error	295	281	334	259

Table 4.10 This table shows the frequency of different reasons for false alarms in different seasons.

4.3.3 Discussion for Seasonal Effect

Rank	Spring		Summer		Autumn		Winter	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	C	25	C	27	C E	24 24	C E	25 25
2	E	22	E	22	-	-	-	-
3	B	18	B	17	B	17	B	17
4	Ma	11	Ma	8	Ma	9	Ma	10
5	O	7	IB O	7 7	O	8	G IB O	6 6 6
6	G IB	6 6	-	-	IB	7	-	-
7	-	-	G	5	G Me	4 4	-	-
8	Me	5	Me	4	-	-	Me	4
9	IF	2	IF	3	IF	2	IF	2

Table 4.11 This table shows the ranks of these different reasons for causing false alarms in different seasons according to the percentage score.

The Environmental Effect (E) did not have a higher percentage value in spring and summer time. Before this study, the author supposed that there would be more pollen and insects in spring and higher temperature in summer. These factors may suggest more environmental type of false alarms, but this hypothesis was not supported by the data. It might be because of Environmental Effect (E) includes not only the natural type of Environmental Effect (E), but also the steam from the shower, and cooking and other man-made type of reasons. Although the pollen, insects and temperature may cause more natural type of Environmental Effect (E) alarms; in autumn and winter people use their heater more and the fumes from the heater would also cause the detectors to activate. People also prefer hot food in winter time; therefore the steam from cooking may also have a higher chance of triggering the AFD system. If the Environmental Effect (E) were subdivided into smaller groups, for example natural type of Environmental Effect (E) and artificial type of Environmental Effect (E), then this question may be a more indicative tool. There is sufficient amount of information from the AFA data to subdivide the Environmental Effect (E) into natural and artificial types; some further study in this effect is encouraged.

4.4 Building Type Effect

The different occupant characteristics in different types of buildings can affect the reasons for cause of the false alarms. For example, the staff in a hospital are always present and have a higher level of alertness to the environment changes. Therefore, it is more likely to have a Good Intent (G) type of false alarms in the hospital. For the shopping malls, because the public has such an easy access to the building, it has a higher chance to have someone activate the fire alarm maliciously.

4.4.1 Dividing the Building Types among the Data

One problem with categorising these buildings is that the building type has only been recorded since June 2000. The fire calls before did not have the building type recorded. The author has solved this problem by three different ways:

1. From the recorded FPA number and address, some building types can be matched with the data after June 2000. If the FPA numbers are the same, and the FPA address (name of the company) has not changed; then it is assumed that the two incidents have the same building type.
2. If there is no traceable record, then the author has categorised the building by its name. Some buildings have obvious names, but some do not. Therefore, some errors when categorising the building types may be introduced.

3. Some records which did not give the name of the building, the author searched the Yellow Pages® website finding some clue about their building types. But this kind of search was not successful every time, because some private accommodation may not be recorded, so some of the apartments may be left out.

After trying all three methods listed, if this building type could still not be identified then this record was omitted.

The building types are divided into the following twelve categories:

Type	Description	Examples
Apartment	Usually an apartment means a room or suite of rooms designed as a residence and generally located in a building occupied by more than one household, but in this report it is a category for all normal residential type of building (dwellings without special care needs).	House, flat, apartment
Community Building/Church	Places open to the public	Airport, memorial hall
Hospital	An institution that provides medical, surgical, or psychiatric care and treatment for the sick or the injured	Hospital, medical centre
Hostel/Boarding House	A supervised, inexpensive long-term lodging place for students and/or young age group.	
Hotel/Motel/ Backpacker	An establishment that provides short-term lodging and usually meals and other services for travellers and other paying guests	YMCA, YHA, Motor inn
Licensed Premise	A commercial place that is given official approval to run the business and serve alcohol	Cafeteria, restaurant
Industrial Facility (Manufactory/ warehouse)	Building with heavy machineries, rough working environmental, and chemicals are expected.	Treatment plant, food process factory
Office	A place in which business, clerical, or professional activities are conducted, and some commercial buildings with a high ratio of staff members to the public, such as flight centre, are also included in this building type	Flight centre, real estate, post office, bank
Prison	A place for the confinement of persons in lawful detention, especially persons convicted of crimes	

Table 4.12a Descriptions and examples of different building types

Type	Description	Examples
Rest Home	An establishment where the elderly or frail are housed and cared for	Nursing home, retirement village
Retail/Mall	The place people can carry out shopping activities	Macdonald, shopping mall
School/ University/ Polytechnic	An institution with education purpose or in some cases where the majority of the building occupants are young	University, children care centre

Table 4.12b Descriptions and examples of different building types (Cont.)

4.4.2 Results for building type effect

	Apartment	Community Building/Church	Hospital	Hostel/Boarding House	Hotel/ Motel	Licensed Premise
Building Work - Builder/Subcontractor	113	300	173	60	199	80
Component Failure	159	365	233	139	395	91
Environmental Effects	364	397	367	267	465	116
Good Intent	37	31	336	23	40	8
Incorrect Building Maintenance	66	151	68	59	73	36
Installation Fault	13	30	21	6	30	10
Malicious	211	191	90	115	137	47
Mechanical Damage	12	60	14	21	42	7
Operator Error	60	79	59	48	72	20

	Industrial Facilities	Office	Prison	Rest Home	Retail/ Mall	School
Building Work - Builder/Subcontractor	378	528	8	105	419	270
Component Failure	897	700	20	245	404	385
Environmental Effects	329	371	15	455	305	390
Good Intent	116	116	1	45	52	45
Incorrect Building Maintenance	137	137	2	88	111	159
Installation Fault	76	38	0	15	46	26
Malicious	74	114	53	27	286	213
Mechanical Damage	371	42	3	8	97	37
Operator Error	222	167	7	96	138	107

Table 4.13 These above tables show the frequency of different false alarm causes in different building types.

4.4.3 Discussion for Building Type Effect

Rank	Apartment		Hospital		Hostel/ Boarding House		Hotel/Motel/ Backpacker		Prison		Rest Home	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	E	35	E	27	E	36	E	32	Ma	49	E	42
2	Ma	20	G	25	C	19	C	27	C	18	C	23
3	C	15	C	17	Ma	16	B	14	E	14	B	10
4	B	11	B	13	B IB	8 8	Ma	9	B	7	O	9
5	IB O	6 6	Ma	7	-	-	IB O	5 5	O	3	IB	8
6	-	-	IB	5	O	7	-	-	Me	3	G	4
7	G	4	O	4	G Me	3 3	G Me	3 3	IB	2	Ma	2
8	IF Me	1 1	IF	2	-	-	-	-	G	1	IF Me	1 1
9	-	-	Me	1	IF	1	IF	2	IF	0	-	-

Table 4.14 This table shows the ranks of these different reasons for causing false alarms in different types of buildings with sleeping facilities in them.

The above table shows the types of building which have sleeping facilities in the place. The apartment type of building has a 35% chance of having an Environmental Effect (E) false alarm. This is not surprising, because of the cooking activities and steam coming from a shower are the potential causes for false alarms. The proportion of Malicious (Ma) type false alarm is also high. This could be because some children activate detection systems for fun, and some drunken people set the systems off.

In a hospital, there was a very high proportion (25%) of Good Intent (G) type of false alarms. The reason for that is believed to be the training that the nursing staff received. The nurses were trained to contact the fire brigade whenever they detect some abnormal situations to ensure the safety of the patients.

The hostels/boarding houses and hotels/motels/backpackers have very similar trends. The ranks of the reasons are alike and the percentage scores are also similar. But in hostels/boarding houses, there is more Malicious (Ma) type of false alarm, which may be because of the drunken occupants in the hostel, while the hotels/motels/ backpackers have more false fire calls due to Component Failure (C).

In a prison, more than half of the false alarms were activated maliciously, which is far more than the second ranked reason, Component Failure (C). There were only a very limited amount of existing data for the prisons, only about 110 cases in the past two years

Rest homes have a very large proportion of Environmental Effect (E) type of false alarms. From the fire call data; there were 455 records of Environmental Effect (E) type of false alarm in rest homes in the past two years. Out of these 455 records, 65 cases (14.2%) were caused by cooking, and 92 (20.2%) fire calls were due to burnt toast. This might suggest that the senior citizens tend to have a higher chance of forgetting about the food they are preparing. One other interesting phenomenon observed is that the Malicious (Ma) type of false alarms is only 2% for the rest home. This may be due to the fact of the restriction on the entrance in this type of building; thus the selected visitors and occupants would prevent the occurrence of Malicious (M) false alarms.

Rank	Community Building/ Church		Licensed Premise		Industrial Facility		Office		Retail/Mall		School/ University/ Polytechnic	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	E	25	E	28	C	35	C	32	B	23	E C	24 24
2	C	23	C	22	B	19	B	24	C	22	-	-
3	B	19	B	19	Me	14	E	17	E	16	B	17
4	Ma	12	Ma	11	E	13	O	8	Ma	15	Ma	13
5	IB	9	IB	9	O	9	IB	6	O	7	IB	10
6	O	5	O	5	IB	5	G Ma	5 5	IB	6	O	7
7	Me	4	IF G Me	2 2 2	G	4	IF Me	2 2	Me	5	G	3
8	G IF	2 2	-	-	IF Ma	3 3	-	-	G	3	IF Me	2 2
9	-	-	-	-	-	-	-	-	IF	2	-	-

Table 4.15 This table shows the ranks of these different reasons for causing false alarms in different types of buildings without sleeping facilities in them.

In Table 4.15 shows the three building categories, community building/church, licensed premise, and school/university/polytechnic have very similar trends. The top rank for these three building types is Environmental Effect (E), which has about 25% possibility. The second highest reason for false alarm is Component Failure (C), which has the score that is very close to the top one, slightly under 25%. Building Work (B) type of false alarm comes after Component Failure (C), and then is Malicious (Ma) type.

The industrial facilities have a very high percentage of Component Failure (C) type of false alarms, and this is likely to be caused by the rough environment. The high environment temperature in a foundry, acidic gas produced during some chemical process, etc. is likely to cause corrosion in components. The Malicious (Ma) false alarm is only 3% of the entire fire calls for industrial buildings. This can be because of the restriction on public entrance and the staff members are not likely to activate fire alarm systems for no reason.

Office building type has a high percentage of Component Failure (C) type false alarms, which is more than 30%. Some further study is needed to find out the reason why this value is this high, but it could simply be because of the unlikelihood of other reasons. There are fewer cooking activities in an office building, which means few Environmental Effect (E) type of false alarm; there is no heavy machinery moving around in an office, which causes fewer Mechanical Damages (Me) to the systems; while the restriction on public access would bring to a halt of people maliciously (Ma) activate the system. A combination of all these reasons listed above could cause the high percentage of the system Component Failure (C) of in an office building.

Because of the easy public access, there is a very high chance of the Malicious (Ma) type of false alarms (15%) in the retail/mall type of buildings. The retail/mall buildings also have a higher chance of Mechanical Damages (Me) to the system, which maybe caused by the trucks accidentally knocked the system off during loading/unloading the goods.

4.5 System Type Effect

As mentioned in Chapter 2, different detection systems are operated by various principles. Therefore the reasons for causing false alarms in diverse types of systems should not be the same. For example, a smoke detector is very sensitive to fumes, dust and insects. Therefore, it is expected to have more Environmental Effect (E) and Incorrect Building Maintenance (IB) types of false alarms. Because a manual type of alarm system needs to be operated manually, it is expected to have more Malicious (Ma) and Good Intent (G) types of false alarms.

4.5.1 Dividing the detection system types

According to the New Zealand Approved Documents C/AS1 [22], the fire safety precautions can be divided into the following different types.

- Type 2 – Manual fire alarm system. This type of alarm systems is activated only by someone operating a manual call point. It is a single or multiple zone system with an alarm panel providing a zone index diagram and defect warning, and suitable for connection to the Fire Service.
- Type 3 – Automatic fire alarm system with heat detectors and manual call points. A detection and fire alarm system, which activates automatically when a pre-determined temperature is exceeded in the space, and can be activated manually at any time.
- Type 4 – Automatic fire alarm system with smoke detectors and manual call points. A detection and fire alarm system which activates automatically in the presence of smoke, and can be activated manually at any time.
- Type 6 – Automatic fire sprinkler system with manual call points. An automatic fire detection, alarm and control system which, when a specified temperature is exceeded in the space, activates the sprinkler head in the affected area and includes alerting devices throughout the building. The system permits alerting devices to be activated manually.
- Type 7 – Automatic fire sprinkler system with smoke detectors and manual call points. An automatic fire alarm system having the same characteristics

as a Type 6 alarm plus an automatic smoke detection system. The fire alarm signal resulting from smoke detection need not be directly transmitted to the Fire Service.

In the provided fire call database, there were some system types called Multiple Control Units (M.C.U.), Sector Panels, and Common Modulators. These systems consist of a control panel that is linked with more than one detection systems; when one of the detection systems activates, the panel will send the fire signal to the Fire Service. It is not possible to identify which system initiates the fire call from the panel. This is an old type of system and is not installed anymore.

The "Other" system type category includes ammonia, deluge, foam deluge, gas detection, gas, gas sensor systems and other miscellaneous systems. The number of systems under "Other" category is very small; there are only 60 available records out of the total of 17,069 records.

4.5.2 Results for Detection System Type Effect

	Type 2	Type 3	Type 4	Type 6+7	Common Modulator	Other
Building Work/Subcontractors	412	724	1567	200	34	7
Component Failure	767	1706	1091	549	179	15
Environmental Effects	151	330	3176	276	27	8
Good Intent	490	82	234	34	12	14
Incorrect Building Maintenance	154	107	833	28	17	1
Installation Fault	49	130	97	41	3	2
Malicious	1034	170	257	120	22	2
Mechanical Damage	103	165	58	403	17	2
Operator Error	294	239	251	326	50	9

Table 4.16 This table shows the frequency of different reasons for false alarms from different fire detection systems.

4.5.3 Discussion for Detection System Type Effect

Rank	Type 2		Type 3		Type 4		Type 6+7		Common Modulator		Other	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	Ma	30	C	47	E	42	C	28	C	50	C	25
2	C	22	B	20	B	21	Me	20	O	14	G	23
3	G	14	E	9	C	14	O	16	B	9	O	15
4	B	12	O	7	IB	11	E	14	E	7	E	13
5	O	9	Ma Me	5 5	G Ma O	3 3 3	B	10	Ma	6	B	12
6	E IB	4 4	-	-	-	-	Ma	6	IB Me	5 5	IF Ma Me	3 3 3
7	-	-	IF	4	-	-	G IF	2 2	-	-	-	-
8	Me	3	IB	3	IF Me	1 1	-	-	G	3	-	-
9	IF	1	G	2	-	-	IB	1	IF	1	IB	2

Table 4.17 This table shows the ranks of these different reasons for causing false alarms from different types of detection systems.

The above table shows that a Type 2 alarm system, manual fire alarm system, is most likely to be activated maliciously (Ma). This may be due to its easy accessibility, because the manual fire alarm system is located at an obvious point and an easily-reached height. One other reason might be because the manual system will be less susceptible to environmental variations. From the existing data, there are 151 incidents with the Environmental Effect (E). The Environmental Effects on a Type 2 system can be rodents had eaten cable, water leaked into the panel, and lightning strikes to the system. Some Environmental Effect (E) type false alarms recorded contained some reporting errors. After reading the description of each case, it was found that there were a few cases when the situation description states it was the smoke activated the smoke detector, but the system type was reported as a manual system.

The mostly likely reason for a Type 3 alarm system, automatic fire alarm system with heat detectors and manual call points, to give a false alarm is because of the Component Failure (C). There is only about 10% of the false alarm rate due to the Environmental Effect (E).

More than 40% false alarm rate of Type 4 systems comes from Environmental Effect (E). As mentioned in Section 2.1, the smoke detection systems are initiated by the presence of aerosol particles, but the systems do not have the ability to differentiate between the products from a real fire and other aerosol particles floating in the air. In this case, a smoke detection system will be activated if any detectable amount of particles enter its chamber, and cause false fire signals.

The sprinkler systems have a relatively high percentage of Mechanical Damage (Me) type false alarms, which is 20%. After looking at the data in more detail, it was found that there were 1,856 false alarm cases coming from the sprinkler systems in the past two years, and 447 of them (about 25%) happened in industrial facilities. In the industrial type of buildings, the sprinkler heads and pipes are exposed and the forklifts and trucks are likely to hit both the sprinkler heads and pipes and cause Mechanical Damage (Me) to the systems.

4.6 *Installation Time Effect*

The time of the system installation could have two different effects. The first effect is the regulation development and system evolution, and the second effect is the building maintenance.

4.6.1 Dividing the Year of Installation

From the fire call data, the oldest system was installed in 1991. The fire call data were divided according to the connected year with time interval of one year.

4.6.2 Results for Year of Installation Effect

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Building Work/Subcontractors	12	327	189	614	419	203	285	483	259	133	17
Component Failure	12	561	368	1018	645	316	367	615	256	138	8
Environmental Effects	11	356	209	512	450	352	525	692	524	297	39
Good Intent	1	63	26	128	100	170	125	179	42	29	2
Incorrect Building Maintenance	2	87	66	203	121	91	153	242	112	59	4
Installation Fault	1	23	14	78	51	19	37	55	23	14	4
Malicious	3	155	106	331	264	116	146	240	147	79	11
Mechanical Damage	3	91	58	183	121	65	53	114	34	20	5
Operator Error	5	120	97	259	146	68	100	218	92	56	7

Table 4.18 This table shows the frequency of different reasons for false alarms from systems installed in different years.

4.6.3 Discussion for Installation Year Effect

Rank	1991		1992		1993		1994		1995	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	B C	24 24	C	31	C	32	C	31	C	28
2	-	-	E	20	E	18	B	18	E	19
3	E	22	B	18	B	17	E	15	B	18
4	O	10	Ma	9	Ma O	9 9	Ma	10	Ma	11
5	Ma Me	6 6	O	7	-	-	O	8	O	6
6	-	-	IB Me	5 5	IB	6	IB Me	6 6	IB Me	5 5
7	IB	4	-	-	Me	5	-	-	-	-
8	G IF	2 2	G	4	G	2	G	4	G	4
9	-	-	IF	1	IF	1	IF	2	IF	2

Rank	1996		1997		1998		1999		2000		2001	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	E	25	E	29	E	24	E	35	E	36	E	40
2	C	23	C	20	C	22	B C	17 17	C	17	B	18
3	B	15	B	16	B	17	-	-	B	16	Ma	11
4	G	12	IB	9	IB	9	Ma	10	Ma	10	C	8
5	Ma	8	Ma	8	Ma O	8 8	IB	8	IB O	7 7	O	7
6	IB	7	G	7	-	-	O	6	-	-	Me	5
7	Me O	5 5	O	6	G	6	G	3	G	4	IB IF	4 4
8	-	-	Me	3	Me	4	IF Me	2 2	IF Me	2 2	-	-
9	IF	1	IF	2	IF	2	-	-	-	-	G	2

Table 4.19 These two tables above show the ranks of these different reasons for causing false alarms from detection systems installed in different years.

From Table 4.19, it is noticed that the systems connected from 1991 to 1995 have Component Failures (C) as their top ranks, while the systems installed from 1996 onwards have more Environmental Effect (C) type false alarms than any other reasons. The systems installed after 1998 have a very high Environmental Effect (E) type false alarm rate. Some further study is required to identify whether there was a revolution in detection system technology or in building regulation. From the above table, the installation year does not seem to have a great effect on the cause of false alarms; therefore this factor was left out of the set of questions.

4.6.4 Dividing Installation Time Length

The length of installation time was worked out by using the year when the fire call was received subtracted by the year when it was connected. Then the data were categorised into different installation time length groups with the time interval of one year.

4.6.5 Results for Installation Time Length Effect

	0	1	2	3	4	5	6	7	8	9	10
Building Work/Subcontractors	151	313	374	293	282	414	472	316	234	88	4
Component Failure	123	372	471	400	394	634	783	567	424	135	1
Environmental Effects	305	563	602	545	419	439	410	308	265	108	3
Good Intent	25	81	143	170	134	105	103	54	39	10	1
Incorrect Building Maintenance	55	130	188	174	106	125	165	100	65	31	1
Installation Fault	15	36	41	44	20	60	43	37	16	8	0
Malicious	77	179	206	160	147	248	265	169	110	36	0
Mechanical Damage	23	43	89	61	73	128	146	93	71	19	1
Operator Error	53	114	159	130	100	133	208	143	82	44	2

Table 4.20 This table shows the frequency of different false alarm causes for different installation time length of systems.

4.6.6 Discussion for Installation Time Length Effect

Rank	0 year		1 year		2 years		3 years		4 years	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	E	37	E	31	E	26	E	28	E	25
2	B	18	C	20	C	21	C	20	C	24
3	C	15	B	17	B	16	B	15	B	17
4	Ma	9	Ma	10	Ma	9	G IB	9 9	Ma	9
5	IB	7	IB	7	IB	8	-	-	G	8
6	O	6	O	6	O	7	Ma	8	IB O	6 6
7	G Me	3 3	G	4	G	6	O	7	-	-
8	-	-	IF Me	2 2	Me	4	Me	3	Me	4
9	IF	2	-	-	IF	2	IF	2	IF	1

Rank	5years		6 years		7 years		8 years		9 years		10 years	
	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%	Symbol	%
1	C	28	C	30	C	32	C	32	C	28	B	31
2	E	19	B	18	B	18	E	20	E	23	E	23
3	B	18	E	16	E	17	B	18	B	18	O	15
4	Ma	11	Ma	10	Ma	9	Me	8	O	9	C G IB Me	8 8 8 8
5	Me O	6 6	O	8	O	8	O	6	Ma	8	-	-
6	-	-	IB Me	6 6	IB	6	IB Me	5 5	IB	6	-	-
7	G IB	5 5	-	-	Me	5	-	-	Me	4	-	-
8	-	-	G	4	G	3	G	3	G IF	2 2	IF Ma	0 0
9	IF	3	IF	2	IF	2	IF	1	-	-	-	-

Table 4.21 The two tables show the ranks of these different reasons for causing false alarms from detection systems with different install time length.

It is noticed in Table 4.21 that the Incorrect Building Maintenance (IB) did not vary much between different installation time lengths, but there were operator error for the systems that have been there for 9 or more years. This might be because the systems are very old and the operators did not have a very good idea about how to operate them. But from the above table, the installation time length does not seem to have great effect on the cause of false alarms; therefore this factor was left out of the set of questions.

4.7 Recommendations for Reducing False Alarms

From the previous sections, some recommendations for the current New Zealand false alarms are made. They are:

1. Applying analogue addressable systems. The advantage of an analogue addressable system is that it can tolerate the variation in environmental conditions. Northey [23] gives credit to analogue addressable systems for their contribution in reducing false alarms. He mentions that:

   "*Information can be stored by the microprocessor and the alarm level can be automatically changed taking into account the environment and the normal signal levels being received from each of the individual detectors. This considerably reduces false alarms. In addition, the information can be used such that an indication is given if a particular detector requires maintenance.*

   Furthermore, in an analogue detector system it is possible to increase the alarm thresholds automatically during working hours (ie decrease the sensitivity of the system to fire) and to programme the system to be more sensitive outside working hours."

By applying analogue addressable systems, it will reduce the Environmental Effect (E) and Incorrect Building Maintenance (IB) types false alarms. This can be a very helpful solution for the issue of false alarm, because Environmental Effect (E) is always one of the top ranks of false alarm causes. The system installation engineer needs to be well trained; Phipps [24] says:

"*A majority of false alarms are actually caused by addressable and analogue addressable systems. Many problems result from initial installation of these systems by companies with engineers whom are inadequately trained and thus do not understand the importance of cable routes and noise interference.*"

2. Introducing the signal delay units to the conventional automatic fire detection systems in order to limit the false alarms. According to the British Standard BS5839: Part 1:1988 [25],

   "*In some (but not all) circumstances where there is a high incidence of false alarms which cannot be reduced by other measures, it may be desirable to delay the automatic transmission of an alarm to the fire brigade for a sufficient time to allow the alarm to be investigated. For this purpose the incorporation of a transmission signal delay unit may be considered.*"

Donohue [26] reported the success in false alarm reduction by adopting signal delay units, he says:

"*Overseas experience with signal delay units has been promising, with a Swiss claim for a reduction in false alarms of as much as 75%.*"

3. Maintaining the fire detection systems regularly. The New Zealand Standard NZS4512:1997, Fire Alarm Systems in Buildings [27] requires smoke detectors in building being clean annually. Visual examination on manual call points should be made frequently to ensure the manual call point glass is not damaged.

4. Educating the nurses and staff in hospitals investigate the situation before activating the manual call points. Section 4.4 shows that there is a high percentage of Good Intent (G) type false alarms in hospitals; this can be improved by educating the nurses and staff carrying out an investigation before initiating manual call points. In the past, the nurses were told to ring the fire bridge at first place when they detect some abnormal situation. This is not necessary nowadays because of the widely use of sprinkler systems in hospital

facilities. Therefore, if the nurses can be educated to investigate the incident before they operate the system, it can be helpful to reduce the number of false alarm in hospitals.

5. Improving the quality of heat detection systems. Section 4.5 suggests that there are about half of the false alarms from a Type 3 (Heat detection system) were caused by Component Failure (C). If the quality of heat detector components can be improved, and this system can be protected from the rough environment; then it will make Type 3 systems more reliable.

6. Attending selected fire alarm calls only under some circumstance. The Fire Service may only attend to the fire calls from automatic fire detection systems if they are confirmed by a call from another source. Herschfield [28] indicates that the Denver Fire Department in United States has considered responding to alarms from automatic fire detection systems only if they are confirmed by a call from another source. A survey conducted in Denver indicated that all unconfirmed automatic fire detection system alarms turned out to be false, while every confirmed automatic fire detection system alarms turned out to be real fires. The author suggests that this selective attendance can only be adopted for the fire calls coming from a smoke detection system, during the day-time, and in urban areas. A smoke detection system usually detects a fire at a very early stage, the time delay for confirmation may still cause some damage to the building but not too severe. If a building is remote from other properties, it would take longer for this fire call to be confirmed by other source. One other option is to have the Fire Service call the building occupants to find out whether it is a genuine fire or not. Some further risk analysis should be carried out before this strategy can be adopted.

7. Protecting the exposed sprinkler pipes and sprinkler heads. These equipments should be protected from the potential sources of Mechanical Damage (Me) such as forklifts, trucks and flying balls.

5.0 Predicting Causes of False Alarms

This chapter combines the previous two chapters to develop a set of questions in ESB to predict the possible reasons for a false fire call.

5.1 Development of ESB for false alarm reasons

Chapter 4 showed that the region where the building is in and the season when the fire call happened do not have a great impact on the reasons for false alarm. Therefore, they were discarded when developing the question sets. The installation time length was also discarded to avoid subdividing the limited amount of available information into too much detail. In the future, it would be useful to be added to the set of questions when there is more data.

Methodology

1. The Question Editor program in ESB was used to build up the question set. The questions, the options to each question, the reliance between questions and the level of importance for each question were entered in the Question Editor program.

Question	Options	Reliance[3]	Importance
1. Did this incident happen during the weekend?	❑ Yes ❑ No	N/A	Medium
2. What time was the fire call?	❑ Breakfast (06.00-09.00) ❑ Lunch (11.00 –14.00) ❑ Dinner (17.00 – 21.00) ❑ Office Hours (09.00-11.00 & 14.00-17.00) ❑ Night-time (21.00 – 06.00)	N/A	Medium
3. Was there any construction work going on in the building?	❑ Yes ❑ No	N/A	High

Table 5.1a The set of questions and possible answer options for predicting the reason for false alarms by using ESB

[3] The reliance means that the question will only appear when a particular answer is chosen.

Question	Options	Reliance	Importance
4. Are there any sleeping facilities in the building?	❑ Yes ❑ No	Q3. Option2	Normal
5. Which category does this building belong to?	❑ Apartment ❑ Hospital ❑ Hostel/Boarding House ❑ Hotel/Motel/Back Packer ❑ Prison ❑ Rest Home	Q4 Option 1	Normal
6. Which Category does this building belong to?	❑ Community Building/Church ❑ Licensed Premise ❑ Manufacturing/Warehouse ❑ Office ❑ Retail Store/Mall ❑ School	Q4 Option 2	Medium
7. What type of detection system is there in the building?	❑ Type 2 (Manual) ❑ Type 3 (Heat detector/Manual) ❑ Type 4 (Smoke detector /Malual) ❑ Type 6+7 (Sprinkler) ❑ Common Modulator/Sector Panel/Multiple Control Unit (MCU) ❑ Other	N/A	High

Table 5.1b The set of questions and possible answer options for predicting the reason for false alarms by using ESB (Cont.)

The importance level of Question1 was assigned to be "Medium" because there is not dramatically different between weekday and weekend results. From Table 4.8, the ranks of false alarm causes varied, but the percentage scores did not have very obvious different. For example, although Component Failure (C) is the top ranked false alarm cause in weekdays, it only has a percentage score of 24%. The Component Failure (C) in weekends is the second ranked, but its percentage score is 26%, which is very similar to the percentage in weekdays. The greatest percentage difference is only 9%, which is difference between the percentages of Building Work (B) in weekdays and weekends, ie. 19% - 10% = 9%

Question 2 was also assigned to be "Medium", because from Table 4.6 the maximum percentage difference between the five time periods is 20%, which is the percentage of Building Work (B) at lunch time subtracted by the percentage of Building Work (B) at night-time, ie. 25% - 5% = 20%

Question 3 was assigned with a level of importance of high because it was assumed that if there is a building work on the site, the false alarm is caused by the contractor or subcontractor (B). In a building without construction work, the possibility of getting a Building Work (B) type false alarm is very low. The existing data has a total of 2,944 Building Work (B) type false alarms, but there were only 548 (less than 20%) cases of Building Work (B) happened in place without construction work. These 548 cases were caused by cleaners, data technicians, electricians, lift engineers, water blasters, and plumbers in normal occupied buildings. Therefore, Question3 should have a high level of importance.

Question 4 was assigned with a normal level of importance. This is because this question is only used to help divide the buildings into different building types. This question can even be omitted if the Question Editor is able to have 12 answer options in a question, since there are 12 building categories. Therefore this question does not have a great influence on the causes of false alarms; a normal importance was given to it.

Questions 5 and 6 were set to have a medium level of importance. This decision was made by trial error method. At first, the author believed the building types should have high level of importance. After trying setting the level of importance of Questions 5 and 6 separately to high level, the outcome is worse than the prediction by setting both of them at medium level. Therefore, the medium importance level was chosen for both questions.

Question 7 has a high level of importance. Different detection system types are operated by different principles, thus the main cause for false alarm in each system is expected to vary from system to system. Table 4.17 shows not only the ranks for the cause of false alarms in the systems, but also the percentage of existing data occurring rates are different between different systems. Therefore, it should be suitable to set the level of importance of Question 7 at high.

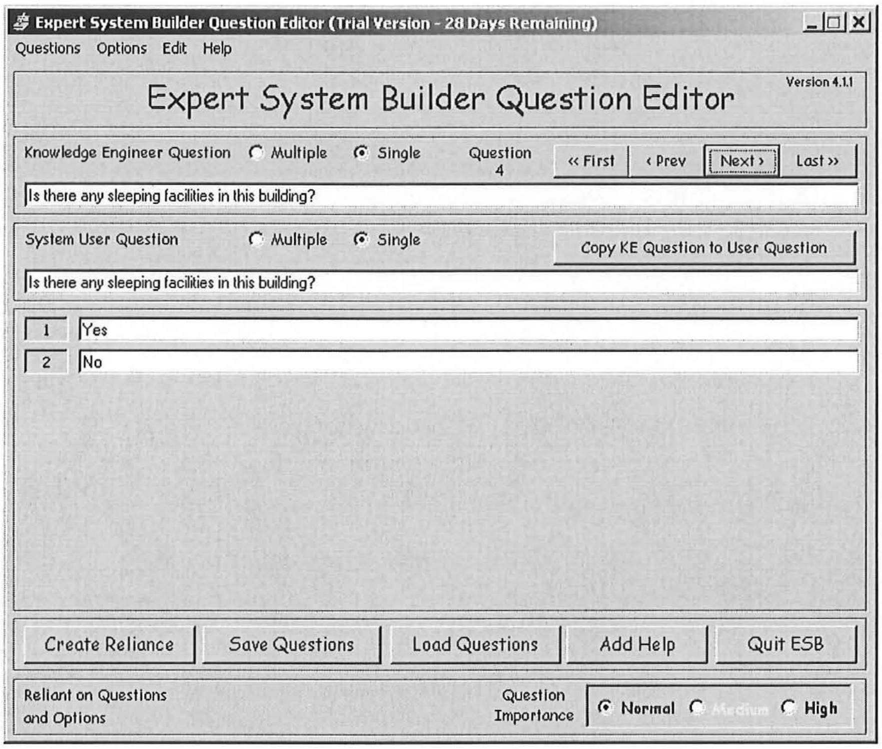


Figure 5.1 This is an example for the question entered in the Question Editor program. This is the fourth question listed in the table above. Please refer to Appendix 4 for pictures of all the questions entered.

2. Knowledge Acquisition program was built according to the reduced fire call data (refer to Section 5.2 for more detail). How to build the Knowledge Acquisition will be discussed in more detail in Section 5.3.
3. There were 24 tests chosen randomly for the purpose of testing the ESB developed (refer to Section 5.4 for the 24 tests), the predicted results from ESB by using User Interface were compared with the existing data to see how good these two match. More description about how to read the analysed result from User Interface is also discussed in Section 5.4.

5.2 Fire Call Data Reduction

In this Section, it described the methods of transforming the existing data into some form that can be used to assist the knowledge base engineer develop the Knowledge Acquisition in ESB.

1. The first step was transforming the data provided by AFA into the EXCEL spreadsheet format. The information provided by AFA was saved in the DBF format, but it can be transferred into the EXCEL format by opening this file from EXCEL spreadsheet, and then saved as .xls. type file. Transferred all data from July 1999 to June 2001 into a single spreadsheet file.
2. Then the fire calls with no description of reason for detection system activation were deleted from the data provided by AFA.
3. The genuine fire calls were excluded from the selected data.
4. These records were sorted into two groups, one group of fire calls happened during weekdays and the other group of fire calls happened during weekends.
5. The fire calls that happened during weekdays group into were categorised into five smaller groups, breakfast, lunch, dinner, office hours, and night-time, according to the time of day when this fire call happened. The same was done with the fire calls happened in weekends.
6. It was assumed that all false alarm incidents happened in a building with some construction work are all due to the Building Work (B), therefore the incidents of false alarm caused by construction workers or some subcontractors were separated from the data for analysis. At this stage, the existing data were sorted into 10 groups according to the day of week and the time of day when this incident happened, and one bulk of cases with some construction at the false alarm incidents.
7. The fire calls were divided according to the building types for each of the ten groups without construction work. There are twelve building type categories; six of them have sleeping facilities in place while the other six do not. The six building types involve sleeping facilities are apartment, hospital, hostel/boarding house, hotel/motel/backpacker, prison and rest home. The six building types without sleeping facilities are community building/church, licensed premise, industrial facility, office, retail/mall and school/university/polytechnic. At this stage, there should be 120 groups without construction works in the buildings and one group of fire calls with construction work on site when the false alarm was given.

8. The 120 groups without building construction work at the incidents were further sorted into six groups according to the fire detection systems installed in place. The six groups are: manual fire safety system (Type 2), heat detection system (Type 3), smoke detection system (Type 4), sprinkler system (Type 6+7), common modulator, and other (including gas detection system ammonia, and other miscellaneous system.) Refer to Appendix 5 for the sorted data.

5.3 Building Knowledge Base

There are two ways to build the knowledge base in ESB. The first method is by simply using the Knowledge Acquisition program, and the other method is by editing the knowledge base using a text editor such as Notepad.

Method #1 – Using Knowledge Acquisition

After loading the questions entered previously in Question Editor, a new record name is created and a suitable description of this record is selected from the answer options. Example 1 shows how to use the sorted data in Appendix 5 and the way to enter a new record by using Knowledge Acquisition program.

Example 1. From the existing data (see Figure 5.2 for how to use the table) the most likely false alarm cause is Environmental Effect when it happened

- During the weekend
- during breakfast time
- without construction work
- in a building with sleeping facilities
- in an apartment
- with a Type 4 detection system

Building with sleeping facilities, apartments

Apartments

Breakfast

Weekend

System	Reason	Breakfast Weekday	Breakfast Weekend	Lunch Weekday	Lunch Weekend
2	Component Failure	2	0	3	1
	Environmental Effect	0	0	1	0
	Good Intend	0	0	2	1
	Incorrect Building Maintenance	0	0	1	0
	Installation Fault	0	0	0	0
	Malicious	4	2	15	5
	Mechanical Damage	0	0	1	0
	Operator Error	1	0	5	0
3	Component Failure	5	5	4	5
	Environmental Effect	1	1	2	3
	Good Intend	3	0	0	0
	Incorrect Building Maintenance	2	0	1	1
	Installation Fault	0	1	0	0
	Malicious	1	1	3	0
	Mechanical Damage	0	0	0	1
	Operator Error	0	0	1	2
4	Component Failure	7	1	5	4
	Environmental Effect	38	11	26	19
	Good Intend	0	6	1	0
	Incorrect Building Maintenance	8	3	4	2
	Installation Fault	0	1	0	0
	Malicious	1	1	0	0
	Mechanical Damage	0	0	0	1
	Operator Error	4	0	7	2

Type 4

* No construction work

Figure 5.2 This figure shows how use the tables in Appendix 5 for Example1.

In the Knowledge Acquisition program, a new record called "Environmental Effect" was created.

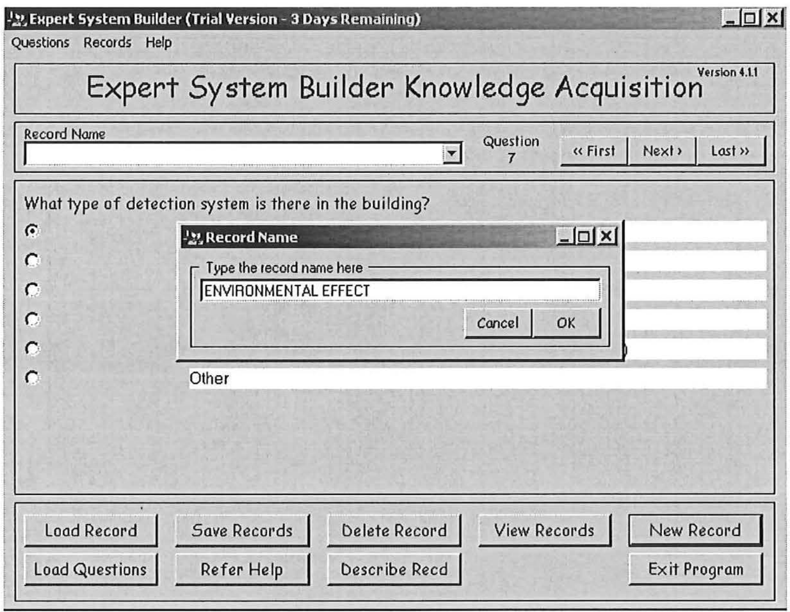


Figure 5.3 Creating a new record called Environmental Effect

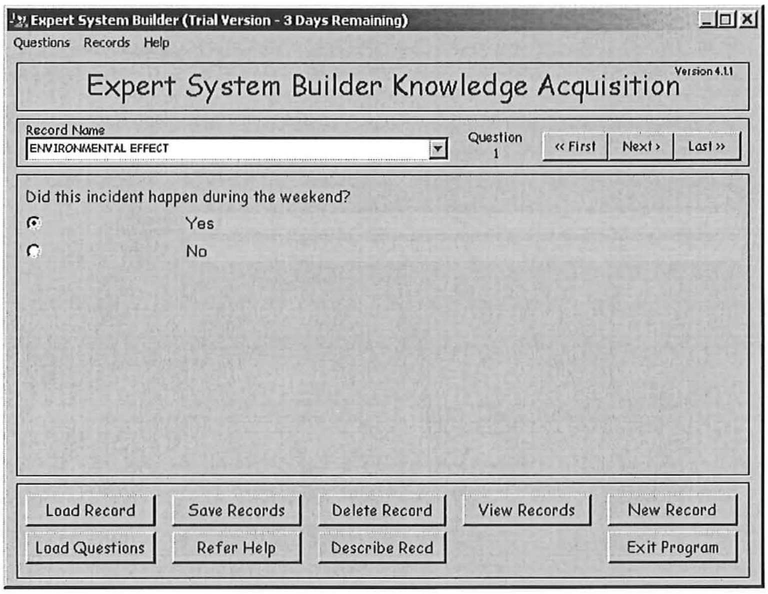


Figure 5.4 This adjacent diagram shows the selected answer for the first question for Example 1. (An incident happened in a weekend)

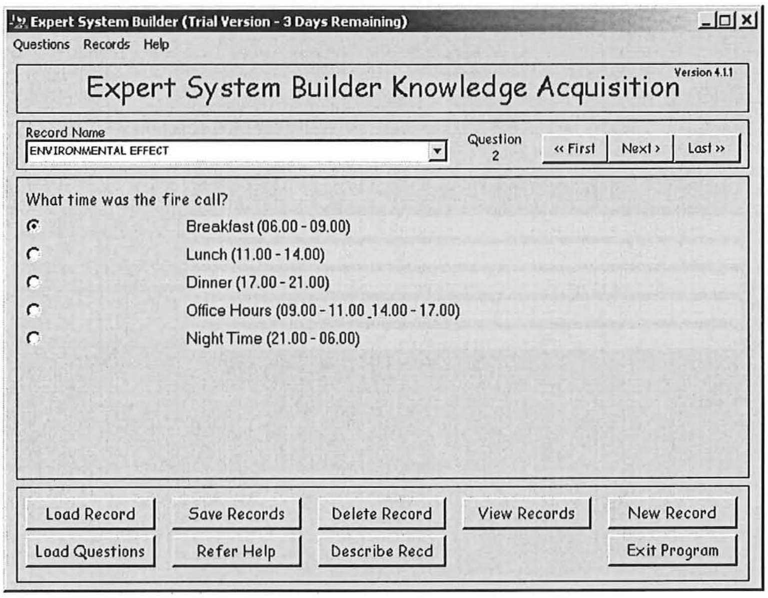


Figure 5.5 This adjacent diagram show the selected answer for the second question for Example 1. (An incident happened during breakfast time)

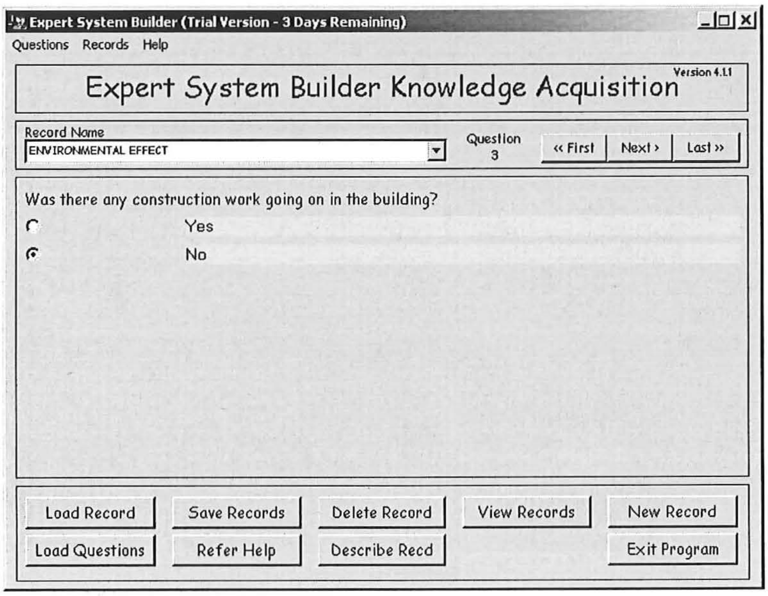


Figure 5.6 This adjacent diagram shows the selected answer for the third question for Example 1. (An incident happened in a building without construction work)

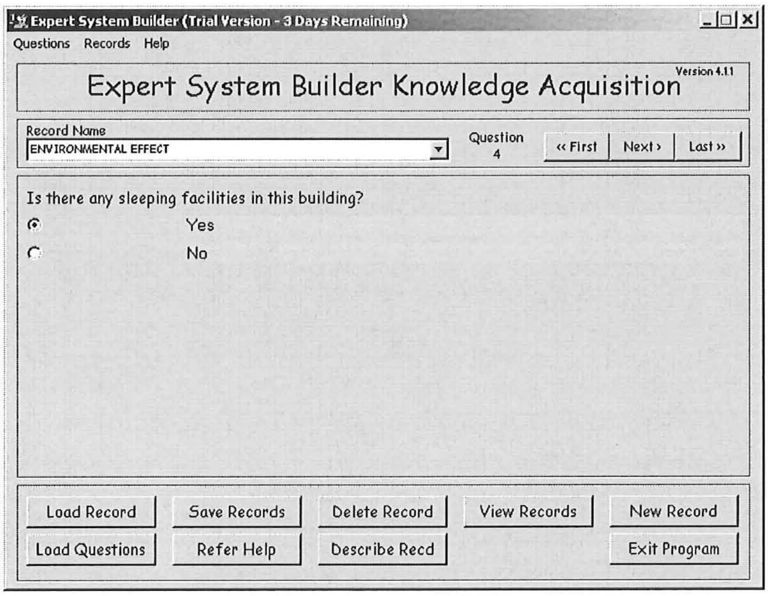


Figure 5.7 This adjacent diagram shows the selected answer for the fourth question in Example 1. (An incident happened in a building with sleeping facilities)

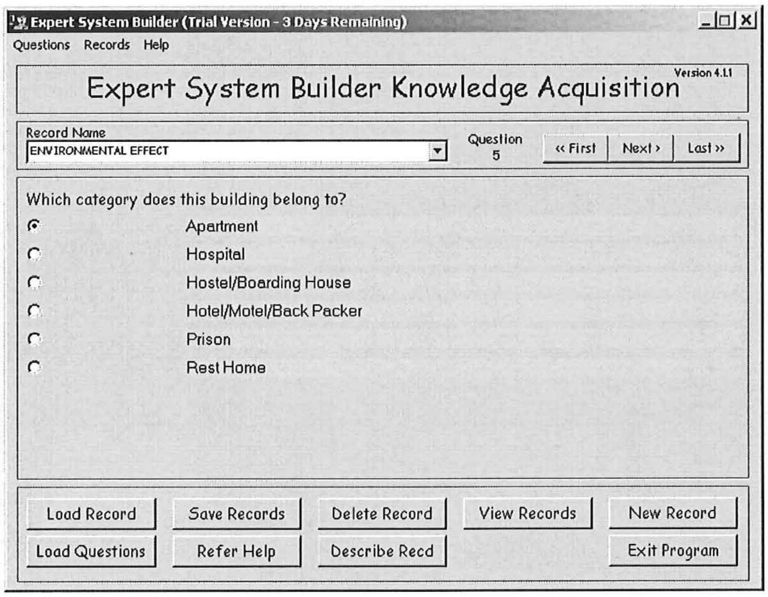


Figure 5.8 This adjacent diagram shows the selected answer for the fifth question in Example 1. (An incident happened in an apartment)

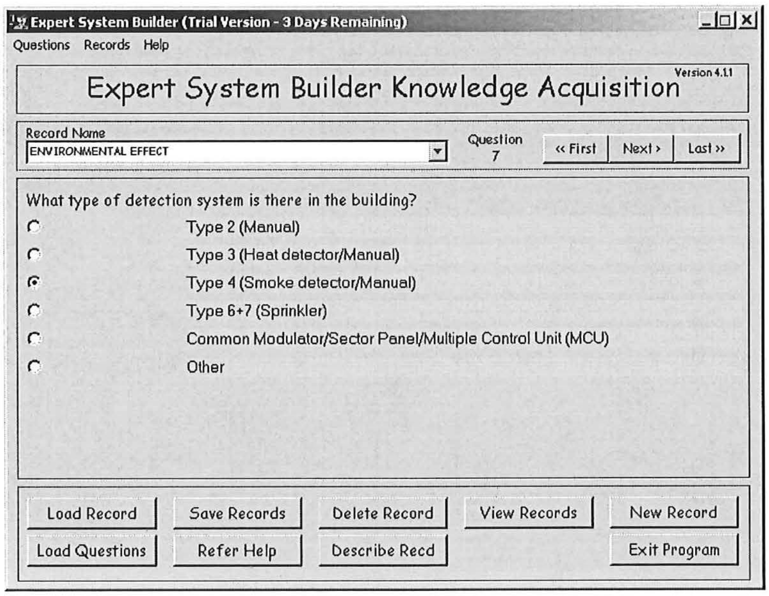


Figure 5.9 This adjacent diagram shows the selected answer for the seventh question in Example 1. (An incident in a building with a Type 4 automatic fire detection system.)

Note that the sixth question did not appear because in the Question Editor program, because Question 6 was set to have the reliance with the building type with no sleeping facilities in the building. Because in this example, an apartment falls in the category of building with sleeping facilities, the sixth question was skipped automatically.

Method #2 – Using Notepad

From the existing data, there are more than one combination of conditions that would lead to the same cause. Sometimes it is possible to put all these conditions under one record.

Example 2. In a hospital, if there is no building work, and the fire safety system in place is a Type 2 system (manual fire safety system), then no matter whether this incident happened during a weekday or at the weekend and what time it occurred, the cause of false alarm would most likely be Good Intent (G).

It is likely to be a Good Intent (G) type false alarm, if the incident:

- happened during either a weekday or at the weekend
- happened at either breakfast, lunch, dinner, office hours or night-time
- happened in a building without construction work
- happened in a building with sleeping facilities
- happened in a hospital
- was activated by a Type 2 system

Building with sleeping facilities, hospital

Hospital

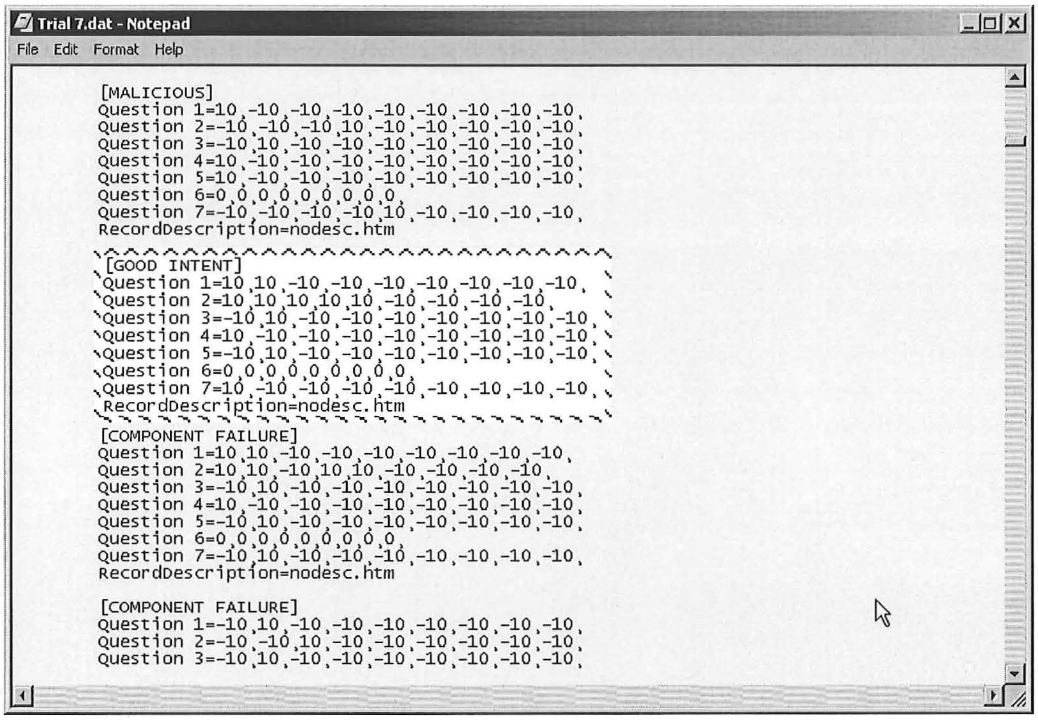
All false alarms caused by Type 2 systems in hospitals, disregarding when the fire calls happened, they are most likely to be Good Intent type false alarm.

Type 2

System	Reason	Breakfast		Lunch		Dinner		Office Hours	
		Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
2	Component Failure	7	1	9	2	7	1	8	2
	Environmental Effect	3	2	3	0	0	0	5	0
	Good Intend	29	11	48	8	28	20	78	11
	Incorred Building Maintenance	0	0	1	0	2	1	2	1
	Installation Fault	1	1	2	0	0	0	0	0
	Malicious	1	2	6	2	9	3	12	6
	Mechanical Damage	0	0	1	0	0	0	1	0
	Operator Error	1	0	7	0	0	0	7	0

* No construction work

Figure 5.10 This figure shows how use the tables in Appendix 5 for Example 2.




```
[MALICIOUS]
Question 1=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 2=-10,-10,-10,10,-10,-10,-10,-10,-10,
Question 3=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 4=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 5=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 6=0,0,0,0,0,0,0,0,0,
Question 7=-10,-10,-10,-10,10,-10,-10,-10,-10,
RecordDescription=nodesc.htm

[GOOD INTENT]
Question 1=10,10,-10,-10,-10,-10,-10,-10,-10,
Question 2=10,10,10,10,10,-10,-10,-10,-10,
Question 3=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 4=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 5=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 6=0,0,0,0,0,0,0,0,0,
Question 7=10,-10,-10,-10,-10,-10,-10,-10,-10,
RecordDescription=nodesc.htm

[COMPONENT FAILURE]
Question 1=10,10,-10,-10,-10,-10,-10,-10,-10,
Question 2=10,10,-10,10,10,-10,-10,-10,-10,
Question 3=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 4=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 5=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 6=0,0,0,0,0,0,0,0,0,
Question 7=-10,10,-10,-10,-10,-10,-10,-10,-10,
RecordDescription=nodesc.htm

[COMPONENT FAILURE]
Question 1=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 2=-10,-10,10,-10,-10,-10,-10,-10,-10,
Question 3=-10,10,-10,-10,-10,-10,-10,-10,-10,
```

Figure 5.11 This above diagram shows how the knowledge base after being modified to represent Example 2 in Notepad.

```
[GOOD INTENT]
Question 1=10,10,-10,-10,-10,-10,-10,-10,-10,
Question 2=10,10,10,10,10,-10,-10,-10,-10,
Question 3=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 4=10,-10,-10,-10,-10,-10,-10,-10,-10,
Question 5=-10,10,-10,-10,-10,-10,-10,-10,-10,
Question 6=0,0,0,0,0,0,0,0,0,
Question 7=10,-10,-10,-10,-10,-10,-10,-10,-10,
RecordDescription=nodesc.htm
```

Figure 5.12 This is the enlarged diagram of the detail of this record.

The above diagram shows the record details about how this record can be modified by using Notepad to represent the conditions mentioned in Example 2. The "GOOD INTENT" in the square brackets is the record name. The question numbers shown on the left hand side match with the questions entered in the Question Editor. The numbers shown in the above diagram are the scores for each option in the question set. For a single type answer (only one answer can be chosen from the set of answers), 10 means this option is selected, -10 means the option is not selected or there is no value entered for this option, and 0 means this option is not relevant to this record.

Recall the question set entered in the Question Editor program:
Question 1 is "Did this incident happen during the weekend?" The two possible options are: 1. "Yes", 2. "No".

In Figure 5.13, the first row under the [GOOD INTENT] represents the first question entered in Question Editor, and it states:

"Question 1=10, 10, -10, -10, -10, -10, -10, -10, -10"

The first "10" on the right hand side of equal sign is the first option, which in this case is "Yes" to Question1. The next "10" is the second option, which in this case is "No" to this question. The rest of the options give the score of "–10", because that by choosing these options, they do not meet the desired conditions for this record.

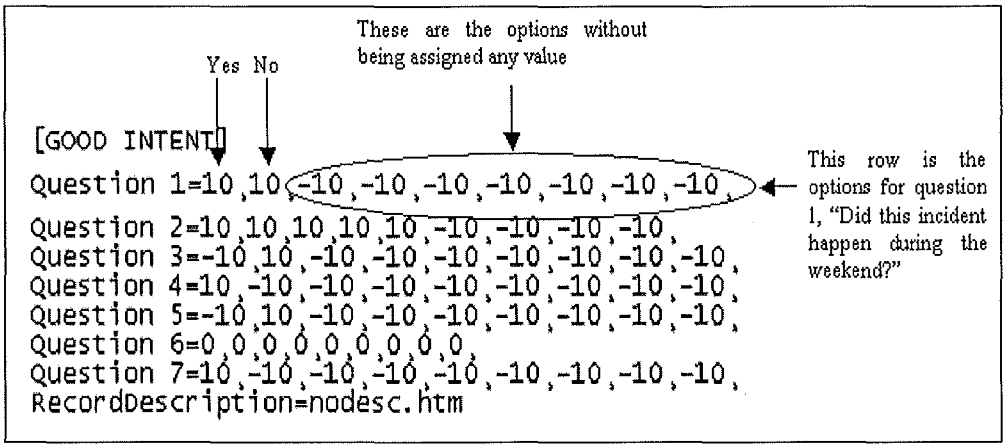


Figure 5.13 This above diagram gives more detailed explanation for the first row under the [GOOD INTENT]

Once again, recall the second question in the question set, "What time was the fire call?" The five answer options are: 1. "Breakfast", 2. "Lunch", 3. "Dinner", 4. "Office Hours", 5. "Night-time".

In Figure 5.14, the second row under the [GOOD INTENT] represents the second question entered in Question Editor, and it states:

"Question 2=10, 10, 10, 10, 10, -10, -10, -10, -10"

The first "10" on the right hand side of equal sign is the first option, which in this case is "Breakfast" to Question2. The next "10" is the second option, which in this case is "Lunch" to this question. Then the following three "10"s represent

"Dinner", "Office Hours", and "Night-time" respectively. The rest of the options give the score of "–10", because that by choosing these options, they do not meet the desire conditions for this record.

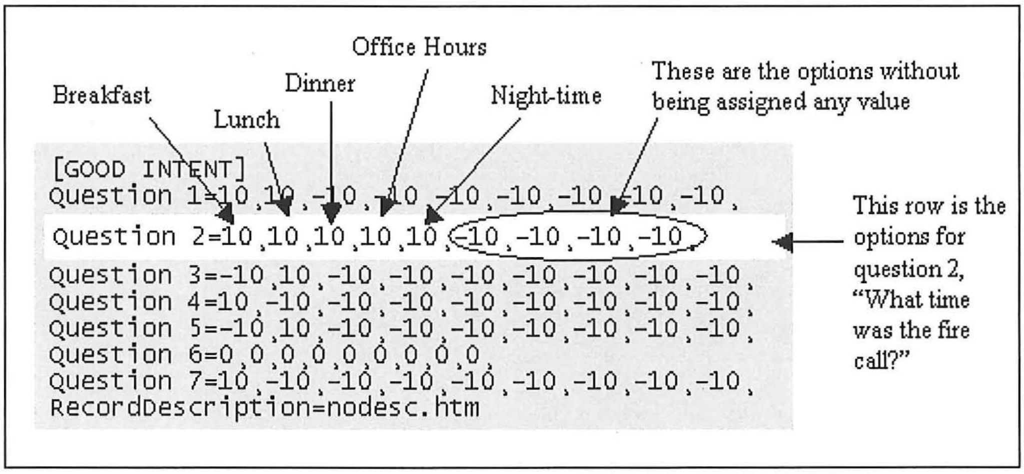


Figure 5.14 This above diagram gives more detailed explanation for the second row under the [GOOD INTENT]

Figure 5.15 demonstrate the two different meanings of a "–10". The first "–10" behind the equal sign represents the option of "Yes" to Question 3. Only the incidents with no construction work in the building meet this record requirement, therefore the first option "Yes" should not be selected. This is why it is assigned with a –10 value. The grouped of seven "-10" values on the right hand side of the "10" were the options without being assigned to any value. From this illustration, it shows how "-10" can mean two different settings in the Knowledge Acquisition system.

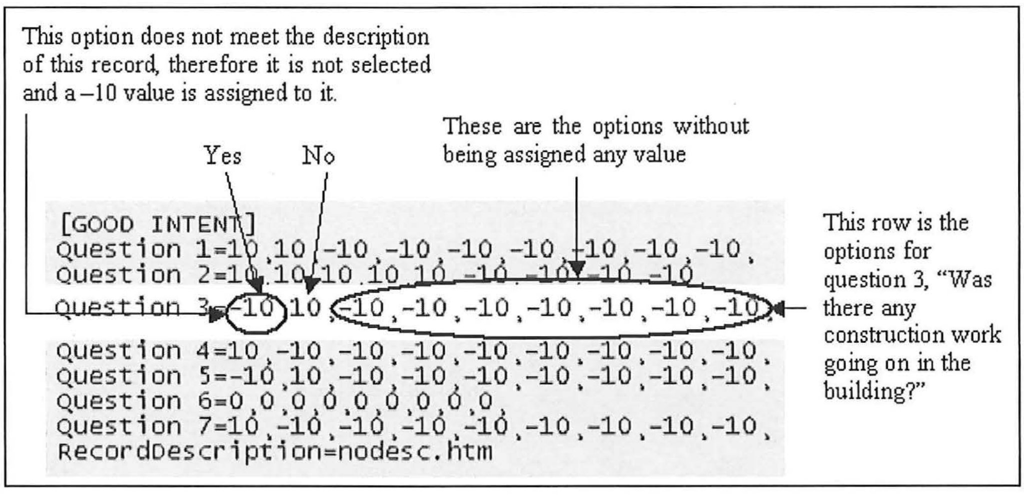


Figure 5.15 this above diagram gives more detailed explanation for the second row under the [GOOD INTENT]

The Notepad file is edited until all the questions are answered. Looking at the scores for the options in Question 6 they are all zeros, this is because of the assigned reliance between Question 6 and Question 4. Question 6 is asked to help divide the buildings without sleeping facilities into the six building type categories: Community Building/Church, Industrial Facility, Licensed Premise, Office, Retail/Mall, and School/University/Polytechnic. Previously, it was set that the Question6 will only be asked if a user chose there are no sleep facilities in the building is answered in Question 4. Because in Example 2, there are sleeping facilities in the hospital building; therefore Question 6 is not asked.

By editing the record from the Notepad, the knowledge base can have more than one combination of settings that will lead to the same record name. Example 2 shows how to edit the setting in a record that can represent 10 different combinations of conditions that are likely to cause Good Intent type of false alarm.

5.4 Tests for ESB

In this Section, the author chose 24 tests (2 for each building type) to compare the results between the existing data and the predicted ones from the ESB. The table at the end of this section (page 68) is a summary for these tests. These tests were chosen semi-randomly from the tables in Appendix 5. Two groups with different features were chosen from each building type, but the data from "Other" detection system type were omitted because of the poor amount of available information.

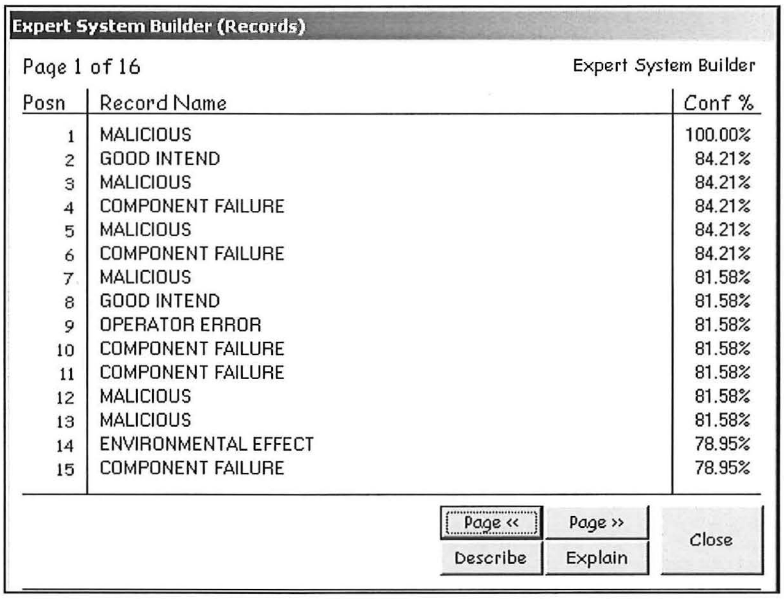
One disadvantage about this program is that because there are many different combinations of situations that can lead to the same cause of false alarms; therefore when the ESB User Interface is used, the user needs to make some judgements to find out the rank of each reason. In Example 3, it explains how to rank the reasons.

Example 3. In Test #1, the situation of an incident is a false fire signal happened:

- on a weekday
- during Office Hours
- in a building without construction work

- in a building with sleeping facilities
- in an apartment
- in a building with a Type 2 detection system

By entering these conditions into the User Interface, the following analysed results were given by the program:



Expert System Builder (Records)

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Posn	Record Name	Conf %
1	MALICIOUS	100.00%
2	GOOD INTEND	84.21%
3	MALICIOUS	84.21%
4	COMPONENT FAILURE	84.21%
5	MALICIOUS	84.21%
6	COMPONENT FAILURE	84.21%
7	MALICIOUS	81.58%
8	GOOD INTEND	81.58%
9	OPERATOR ERROR	81.58%
10	COMPONENT FAILURE	81.58%
11	COMPONENT FAILURE	81.58%
12	MALICIOUS	81.58%
13	MALICIOUS	81.58%
14	ENVIRONMENTAL EFFECT	78.95%
15	COMPONENT FAILURE	78.95%

Page << | Page >> | Describe | Explain | Close

Figure 5.16 This figure shows the analysis from the Expert System Builder for Example 3.

The Conf % values in the above diagram can be used as a tool for ranking the reasons. Each percentage shows the match between the options selected and the conditions for those records entered into the knowledge base. In this figure, many repeated record names are shown; this is because there are many different situation descriptions that will lead to the same cause of false alarms. A user needs to note down the confidence percentage of each reason when it first appear on the screen, then from the confidence percentage score, the reasons can be ranked.

For Example 3, the first record named "MALICIOUS" appears with the confidence of 100%. The first appeared "GOOD INTENT" has an 84.21% score. The next record is "COMPONENT FAILURE", which also has an 84.21%. Note that "MALICIOUS" appears again on the third row in this result page with 84.21% confidence percentage, but because "MALICIOUS" has already been noted down, this record is omitted. The final scores for each reason are summarised in the following table:

Reason (Record Name)	Percentage Score (%)	Rank
Malicious	100	1
Good Intent	84.21	2
Component Failure	84.21	2
Operator Error	81.58	4
Building Work – Contractor/Subcontractor	78.95	5
Environmental Effect	78.95	5
Mechanical Damage	63.16	7
Installation Fault	60.53	8
Incorrect Building Maintenance	60.53	8

Table 5.2 This table shows the percentage scores of the eight causes of false alarm and rank them according to the percentage scores for Example 3.

		Building Types (Q4, 5, 6)																							
		1.5 Buildings with sleeping facilities												***1.6 Buildings without sleeping facilities***											
		A		B		C		D		E		F		G		H		I		J		K		M	
	Test #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Q1. Did this incident happen during the weekend?	Yes		√					√											√				√	√	√
	No	√		√	√	√	√		√	√	√	√	√	√	√	√	√	√		√	√	√			
Q2. What time was the fire call?	Breakfast			√								√				√					√	√			
	Lunch				√						√				√					√					
	Dinner		√						√															√	
	Office Hour	√						√					√				√								
	Night Time					√	√			√				√				√	√				√		√
Q7. What type of detection system is there in the building?	Type 2	√		√		√				√		√													
	Type 3						√	√						√						√		√			
	Type 4		√		√				√				√			√		√					√	√	
	Type 6+7										√						√		√		√				√
	MCU														√										
	Other																								

The building types in the above table are:

- A – Apartments
- B – Hospitals
- C – Hostels/Boarding Houses
- D – Hotels/Motels/Backpackers
- E – Prisons
- F – Rest Homes
- G – Community Buildings/Churches
- H – Licensed Premises
- I – Manufacturing Places/Warehouses
- J – Offices
- K – Retails/Malls
- L – Schools/Universities/Polytechnics

5.5 Comparison of ESB Prediction and Existing Data

The existing data were ranked by the frequency of false alarms for each reason, the lower the rank, the higher frequency in the historic data it had. If there is no existing false alarm data for a particular reason, then a rank "9" is given to that cause. Then these ranked results were compared with the predictions from the ESB.

Example 4. The ranks for the reasons of a false alarm with the condition specified in Test #1 from the existing data can be found as described below:

This following figure shows the existing data for the number of false alarms that happened during the office hours in weekdays in apartment buildings with Type 2 systems where there was no construction work on site.

Apartments

System	Reason	Office Hours	
		Weekday	Weekend
2	Building Work - Contractor/Subcontractor	1	0
	Component Failure	9	4
	Environmental Effect	1	0
	Good Intent	8	0
	Incorrect Building Maintenance	3	1
	Installation Fault	2	0
	Malicious	17	5
	Mechanical Damage	0	0
	Operator Error	11	0

Figure 5.17 This is the statistics of existing data for Test #1.

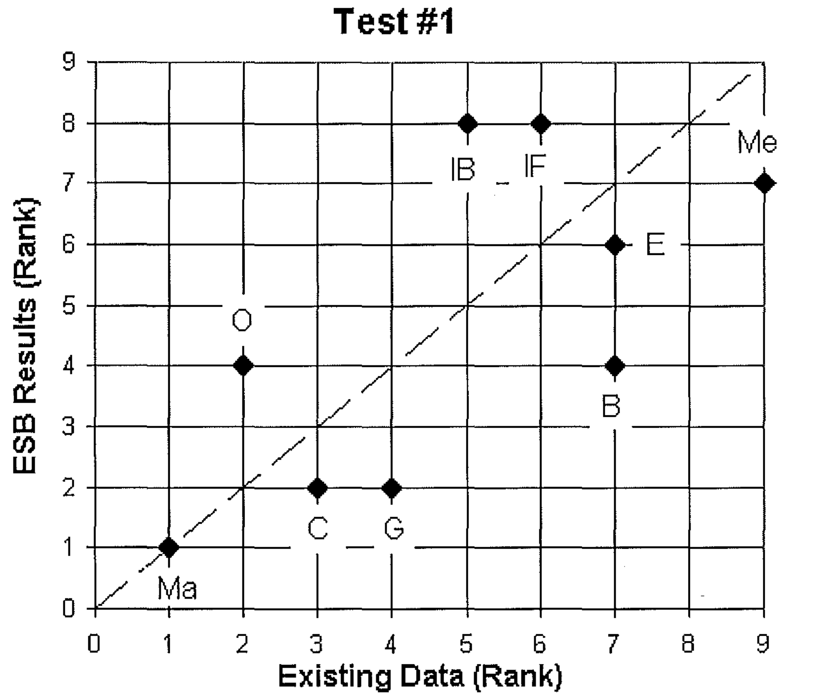
Reason (Record Name)	Frequency	Rank
Malicious	17	1
Operator Error	11	2
Component Failure	9	3
Good Intent	8	4
Incorrect Building Maintenance	3	5
Installation Fault	2	6
Environmental Effect	1	7
Building Work – Contractor/Subcontractor	1	7
Mechanical Damage	0	9

Table 5.3 This table shows the frequency of the nine causes of false alarms and rank them according to the number of exiting incidents for Example 4.

Comparison for Test #1

	Existing Data	**Expert System Builder**
1	Malicious	Malicious
2	Operator Error	Good Intent Component Failure
3	Component Failure	-
4	Good Intent	Building Work Operator Error
5	Incorrect Building Maintenance	-
6	Installation Fault	Environmental Effect
7	Environmental Effect Building Work[4]	Mechanical Damage
8	-	Installation Fault Incorrect Building Maintenance
9	Mechanical Damage	

Table 5.4 Comparison between the existing data and the prediction from ESB for Test #1.



Key

Component Failure	C	Installation Fault	IF
Environmental Effect	E	Malicious	Ma
Good Intend	G	Mechanical Damage	Me
Incorrect Building Maintenance	IB	Operator Error	O

Figure 5.18 This graph shows the comparison results between the existing data and ESB results. If the ESB results match perfectly with the existing data, then the points should fall on the 45° line.

[4] The Building Work (B) type of false alarms here only includes cleaners, data technicians, electrician, lift engineers, water blasters, plumbers and refrigerator engineers.

From Figure 5.18, the difference between these points and the 45° line can be found by taking the absolute value of the difference between the two ranks. For example, in Test #1, the difference between these points and the 45° line are:

Building Work (B)	: $\lvert 7-4 \rvert$	= 3
Component Failure (C)	: $\lvert 3-2 \rvert$	= 1
Environmental Effect (E)	: $\lvert 7-6 \rvert$	= 1
Good Intent (G)	: $\lvert 4-2 \rvert$	= 2
Incorrect Building Maintenance (IB)	: $\lvert 5-8 \rvert$	= 3
Installation Fault (IF)	: $\lvert 6-8 \rvert$	= 2
Malicious (Ma)	: $\lvert 1-1 \rvert$	= 0
Mechanical Damage (Me)	: $\lvert 9-7 \rvert$	= -
Operator Error (O)	: $\lvert 2-4 \rvert$	= 2
	Sum	= 14

14 is the total difference between the data point and the 45° line.

Some cases have no existing data for some particular reason groups. If the ESB predicts a particular reason has a rank greater or equal to 7 (means it is not likely the cause for a false alarm) and there is no existing data, then this point can be discarded when calculating the total vertical distance between the points and the 45° line. The Mechanical Damage (Me) is an example. This is only an arbitrary decision to help the author evaluate the 24 tests.

The comparison results of all the 24 tests can be found in Appendix 6. The same calculation was carried out for each of them. The total difference between the points and the 45° line, and the number of available points are summarised in the following table.

Test #	Difference	No. of ranks assessed	Average difference for one rank
1	14	8	14 / 8 = 1.75
2	21	7	21 / 7 = 3.00
3	13	7	13 / 7 = 1.86
4	13	9	13 / 9 = 1.44
5	17	8	17 / 8 = 2.13
6	32	9	32 / 9 = 3.56
7	16	8	16 / 8 = 2.00
8	23	9	23 / 9 = 2.56
9	14	6	14 / 6 = 2.33
10	7	7	7 / 7 = 1.00
11	21	7	21 / 7 = 3.00
12	18	8	18 / 8 = 2.25
13	17	9	17 / 9 = 1.89
14	28	7	28 / 7 = 4.00
15	23	8	23 / 8 = 2.88
16	12	7	12 / 7 = 1.71
17	8	9	8 / 9 = 0.89
18	5	6	5 / 6 = 0.83
19	12	8	12 / 8 = 1.50
20	18	8	18 / 8 = 2.25
21	16	8	16 / 8 = 2.00
22	8	7	8 / 7 = 1.14
23	19	7	19 / 7 = 2.71
24	12	6	12 / 6 = 2.00

Table 5.5 The summary of the performance of these 24 tests.

The rank of performance of these 24 tests according to the average difference for one point is listed in Table 5.6. The smaller value the difference per rank in Table 5.5 has, the better match between ESB and existing data it is.

Rank	Test #	Difference per rank	Rank	Test #	Difference per rank
1	18	0.83	11	24	2.00
2	17	0.89	14	5	2.13
3	10	1.00	15	12	2.25
4	22	1.14	15	20	2.25
5	4	1.44	17	9	2.33
5	19	1.50	18	8	2.56
7	16	1.71	19	23	2.71
8	1	1.75	19	15	2.88
9	3	1.86	21	2	3.00
10	13	1.89	21	11	3.00
11	7	2.00	23	6	3.56
11	21	2.00	24	14	4.00

Table 5.6 The tests ranked according to their performance.

This following graph shows the number of incidents that meet the descriptions of each test versus the rank of these 24 tests. These 24 tests were equally divided into 4 groups, and each group consists of six tests.

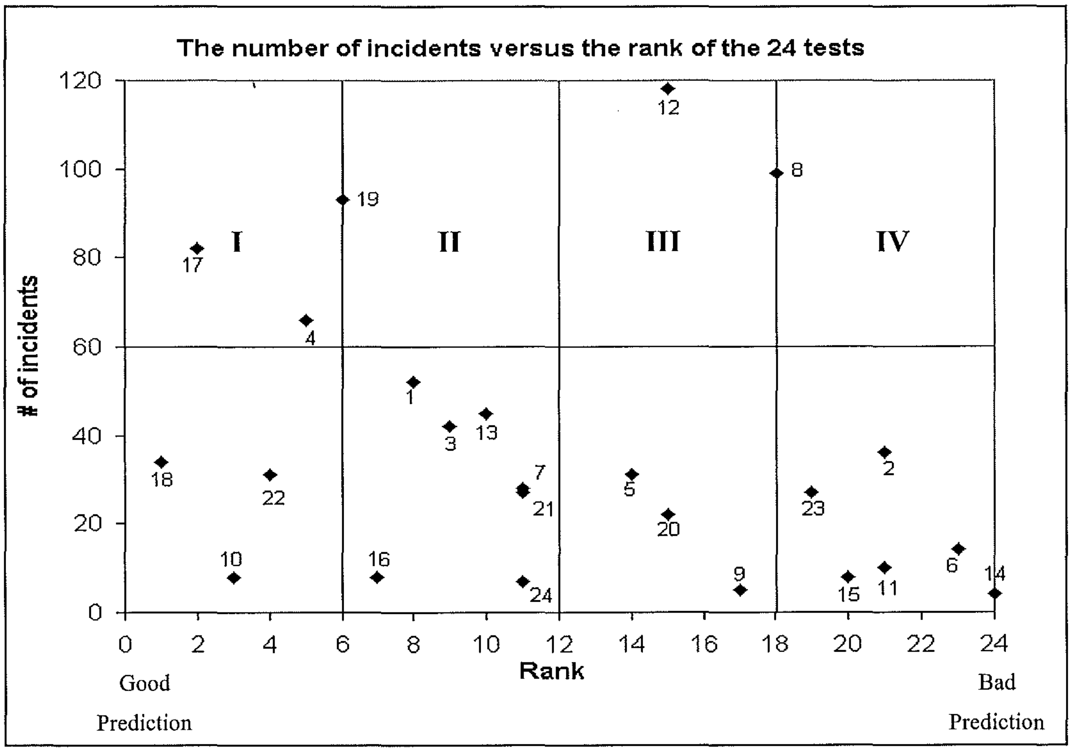


Figure 5.19 This above graph shows the number of incidents versus the rank for each of the 24 tests. The number near the point is the test series number.

Figure 5.19 divided the 24 tests into four equal divisions. Division one consists of the top six ranked tests; they are Tests 18, 17, 10, 22, 4 and 19. Tests 4,17 and 19 have more than 60 incidents in the database; this might suggest that the more existing data, the better estimation the expert system can make.

Test 10 is the third top rank for false alarm causes, but it only has eight incidents. This is because in the knowledge base, the top reasons from the existing data were entered in the ESB Knowledge Acquisition for predicting the possible false alarm cause. Figure 5.20 shows that from the existing data there are three reasons, Component Failure (C), Malicious (Ma) and Mechanical Damage (Me), ranked as the top likely cause for this situation; therefore they were set in the Knowledge Acquisition to be the most like reasons for false alarm for Test 10. Therefore it leaves this test with less uncertainty and suggests a better performance. Test 10 also has two points (Good Intent (G) and Installation Fault (IF) types) that were omitted when calculating the total vertical distance between the points and 45° line because they are on the y-axis and has the y value greater or equal to 7.

Prison

System	Reason	Lunch	
		Weekday	Weekend
6+7	Building Work - Contractor/Subcontractor	0	0
	Component Failure	2	1
	Environmental Effect	0	0
	Good Intend	0	0
	Incorrect Building Maintenance	1	0
	Installation Fault	0	0
	Malicious	2	0
	Mechanical Damage	2	0
	Operator Error	1	0

Figure 5.20 This is the statistics of existing data for Test #10.

Test #10

		Existing Data	ESB	Difference
Building Work/Subcontractor	B	9	6	3
Component Failure	C	1	1	0
Environmental Effect	E	9	6	3
Good Intend	G	9	9	-
Incorrect Building Maintenance	IB	4	5	1
Installation Fault	IF	9	8	-
Malicious	Ma	1	1	0
Mechanical Damage	Me	1	1	0
Operator Error	O	4	4	0
			Sum	7

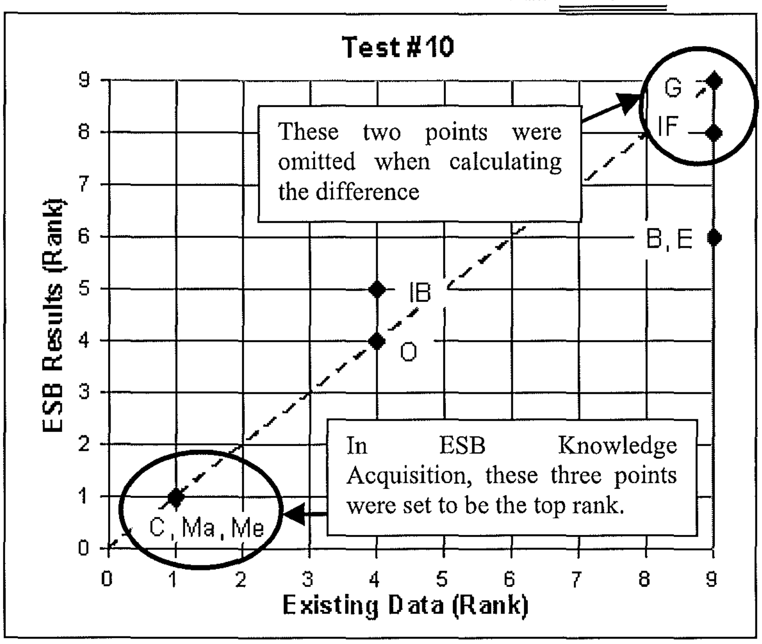
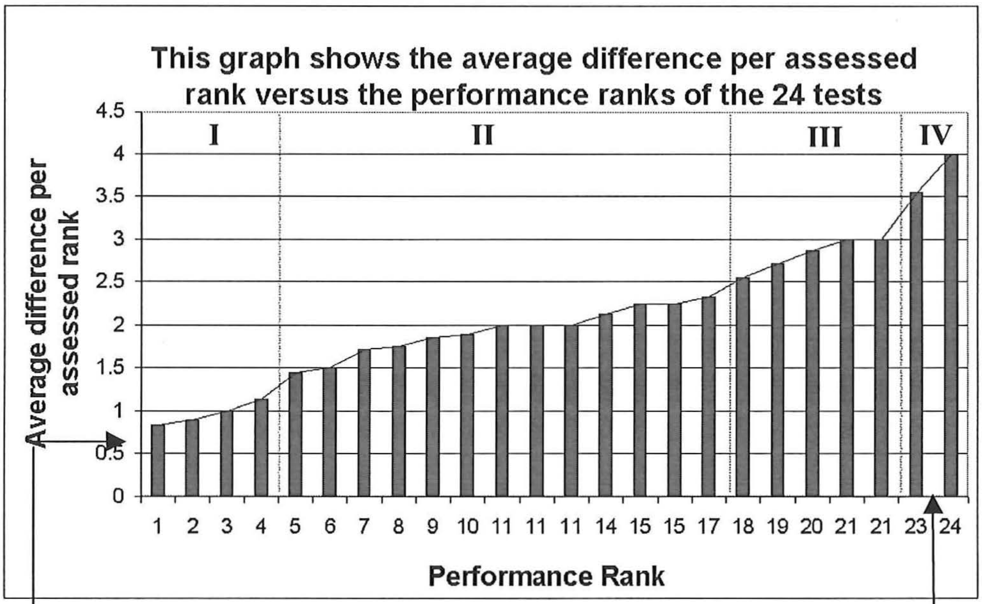


Figure 5.21 This above figure is the performance comparison between the existing data and ESB prediction results for Test 10

From Figure 5.19, there are two points (Tests 8 and 12) with a large number of incident records but still located in Division III. In Test 8, although there are 99 incidents, 75 incidents (77%) were caused by the same reason. Test 12 also has the same trend; there are 69 incidents out of 118 (about 59%) caused by one reason. It might be the uneven distribution of the existing data that affects the accuracy of ESB prediction.

In Division IV, all of the tests have fewer than 40 incidents. This might suggest that the fewer existing data the less accurate prediction it will have.

Another method was tried to divide up the groups. A histogram graph was plotted according to the average difference per assessed rank versus its performance rank of the 24 tests from Table 5.6.



Rank	Test #	Difference per rank	Rank	Test #	Difference per rank
1	18	0.83	11	24	2.00
2	17	0.89	14	5	2.13
3	10	1.00	15	12	2.25
4	22	1.14	15	20	2.25
5	4	1.44	17	9	2.33
5	19	1.50	18	8	2.56
7	16	1.71	19	23	2.71
8	1	1.75	19	15	2.88
9	3	1.86	21	2	3.00
10	13	1.89	21	11	3.00
11	7	2.00	23	6	3.56
11	21	2.00	24	14	4.00

Figure 5.22Histogram graph for the 24 tests.

In Figure 5.22, the 24 tests were divided up into four groups according to the slope. The first group consists of four tests; they are Tests 18, 17, 10 and 22. Tests 17 and 18 are both the scenarios taking from industrial facility type buildings. It is not certain whether it means the ESB can predict industrial facility scenarios or it was just a coincidence. Some more tests may be required in order to draw a conclusion on that.

The last group, Group IV, which has the worst matches between the ESB and existing data, consists of Tests 14 and 6. These three tests have fewer than 15 incidents, which suggests that the accuracy of ESB prediction will be reduced if there is not sufficient amount of existing records.

5.6 Recommendations for Future Development

This is the author's first attempt of using the ESB; it is only at the infancy stage. The limited amount of time and available data means that there are still some room for improvement in ESB development and a more in-depth investigation into the fire calls can be conducted. Further work could include:

- Collecting more fire call incidents. Due to the limitation in the amount of existing data, after subdividing the incidents into groups only very few incidents were left in each group. Therefore if more data can be collected, it will be helpful to find out how good the prediction from Expert System Builder is.
- Try different level of importance for each question. The Expert System Builder can assign different level of importance to each question in the Question Editor program. By varying the level of importance may be able to give a better prediction to the existing data.
- Try the Expert System Builder for all the combinations of different conditions. Instead of doing only 24 tests, all different situations should be tested.
- Vary the question set. Some other questions may be useful to help predict false alarm causes are:
    1. Which year this system was connected?
    2. Which season was it? (This is helpful if the Environmental Effect is split into natural and artificial types of Environmental Effect.)
    3. What model make was the system? (One disadvantage is this detail was only recorded after June 2000.)
    4. When this system was connected?

6.0 Conclusions

From this report, the following points were found:

- False alarms are a costly issue from both economic and life safety points of view.

- It is found from the literature review that the false alarm rate in New Zealand is lower than the statistics in Tasmania (Australia), but higher than what they have in the United States and London.

- In the general case, the top three causes for false alarms in New Zealand are Building Work (B), Component Failure (C), and Environmental Effect (E).

- This report shows that the false alarm calls from different fire region have similar characteristics. The seasonal effect is not very obvious from the two years fire call data provided.

- Human activities, building types, and different detection systems impose great impacts on the false alarm types.

- A fire alarm system installed before 1995 has a very high rate of getting a Component Failure (C) type alarm, while the systems installed later have more Environmental Effect (E) type false alarms. It appears that the longer the system has been installed, the less familiar a technician will be.

- The false alarms can be reduced through:
    - Using analogue addressable systems
    - Introducing the signal delay units
    - Maintaining a detection system at a good working state
    - Educating the nurses and staff in hospital do some investigation before ring the alarm system
    - Improving the quality of heat detection systems
    - Confirming with the building occupants before the fire bridge attending the automatic alarm calls
    - Protecting the exposed sprinkler pipes and sprinkler heads.

- This idea of applying Expert Systems for predicting the cause of false alarms is achievable.

- During the ESB development process, it was found that the Knowledge Acquisition in ESB can be entered either by using the Knowledge Acquisition or a text editor such as Notepad.

- From the comparison results of the 24 tests between the existing data and prediction from ESB, it shows that the more data that is available, the better prediction the ESB can make.

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Appendix 1 National Summary of All Fire Service Emergency Incidents

1995/96	Urban	Rural	Total
All Fires	14,647	3,237	17,884
Structural Damage Fires	2,155	520	2,678
Overpressure, Rupture	447	23	470
Rescues, Emergency Medical	703	469	1,172
Hazardous Emergencies	3,766	1,311	5,077
Special Service	2,628	748	3,376
False Alarm – Good Intent	4,144	1,004	5,148
False Alarm – Other[5]	12,203	402	12,605
Natural Disaster	722	64	786
Mutual Aid	15	20	35
Grand Total[6]	**39,275**	**7,278**	**46,553**

Table 1.1 National Summary of all incidents for fire service year 1995/1996. This table was reproduced from the Fire Service Emergency Incident Statistics edition for 1999/2000 Corporate Year.

1996/97	Urban	Rural	Total
All Fires	16,907	3,646	20,553
Structural Damage Fires	2,145	495	2,640
Overpressure, Rupture	451	16	467
Rescues, Emergency Medical	1,123	496	1,619
Hazardous Emergencies	4,179	1,749	5,928
Special Service	3,773	806	4,579
False Alarm – Good Intent	4,598	1,117	5,715
False Alarm – Other	13,933	504	14,437
Natural Disaster	888	86	974
Mutual Aid	12	23	35
Grand Total	**45,864**	**8,443**	**54,307**

Table 1.2 National Summary of all incidents for fire service year 1996/1997. This table was reproduced from the Fire Service Emergency Incident Statistics edition for 1999/2000 Corporate Year.

[5] Includes malicious, defective apparatus, accidental operation etc.

[6] The grand total will not equal the Station Statistics due to some stations not having a parent region.

1997/98	Urban	Rural	Total
All Fires	19,818	4,473	24,291
Structural Damage Fires	2,150	408	2,558
Overpressure, Rupture	415	22	437
Rescues, Emergency Medical	2,182	468	2,650
Hazardous Emergencies	4,574	1,527	6,101
Special Service	3,904	951	4,855
False Alarm – Good Intent	5,334	1,246	6,580
False Alarm – Other	15,305	602	15,907
Natural Disaster	822	41	863
Mutual Aid	17	29	46
Grand Total	**52,371**	**9,359**	**61,730**

Table 1.3 National Summary of all incidents for fire service year 1997/1998. This table was reproduced from the Fire Service Emergency Incident Statistics edition for 1999/2000 Corporate Year.

1998/99	Urban	Rural	Total
All Fires	17,027	4,448	21,475
Structural Damage Fires	1,695	445	2,140
Overpressure, Rupture	396	18	414
Rescues, Emergency Medical	2,525	365	2,890
Hazardous Emergencies	4,797	2,368	7,165
Special Service	4,386	916	5,302
False Alarm – Good Intent	5,614	1,515	7,129
False Alarm – Other	16,652	888	17,540
Natural Disaster	1,787	289	2,076
Mutual Aid	29	37	66
Grand Total	**53,213**	**10,844**	**64,057**

Table 1.4 National Summary of all incidents for fire service year 1998/1999. This table was reproduced from the Fire Service Emergency Incident Statistics edition for 1999/2000 Corporate Year.

1999/2000			
	Urban	**Rural**	**Total**
All Fires	15,989	3,933	19,922
Structural Damage Fires	1,837	424	2,261
Overpressure, Rupture	395	37	432
Rescues, Emergency Medical	950	298	1,248
Hazardous Emergencies	4,648	2,777	7,425
Special Service	4,076	868	4,944
False Alarm – Good Intent	5,081	1,417	6,498
False Alarm – Other	16,903	995	17,898
Natural Disaster	773	96	869
Mutual Aid	2	0	2
Grand Total	**48,817**	**10,421**	**59,238**

Table 1.5 National Summary of all incidents for fire service year 1999/2000. This table was reproduced from the Fire Service Emergency Incident Statistics edition for 1999/2000 Corporate Year.

Appendix 2 Percentage of False Alarm Calculation

95/96

1995/96	
	Total (Urban and Rural)
False Alarm – Good Intent	5,148
False Alarm – Other	12,605
Grand Total	46,553

Total number of false alarm in 1995/96 fire service year is: 5,148 + 12,605 = 17,753

The grand total number of emergency call incidents is: 46,553

The percentage of false alarm calls is 17,753 / 46,553 = 38.1%

96/97

1996/97	
	Total (Urban and Rural)
False Alarm – Good Intent	5,715
False Alarm – Other	14,437
Grand Total	54,307

Total number of false alarm in 1996/97 fire service year is: 5,715 + 14,437 = 20,152

The grand total number of emergency call incidents is: 54,307

The percentage of false alarm calls is 20,152 / 54,307 = 37.1%

97/98

1997/98	
	Total (Urban and Rural)
False Alarm – Good Intent	6,580
False Alarm – Other	15,907
Grand Total	61,730

Total number of false alarm in 1997/98 fire service year is: 6,580 + 15,907 = 22,487

The grand total number of emergency call incidents is: 61,730

The percentage of false alarm calls is 22,487 / 61,730 = 36.4%

98/99

1998/99	
	Total (Urban and Rural)
False Alarm – Good Intent	7,129
False Alarm – Other	17,540
Grand Total	64,057

Total number of false alarm in 1998/99 fire service year is: 7,129 + 17,540 = 24,669

The grand total number of emergency call incidents is: 64,057

The percentage of false alarm calls is 24,669 / 64,057 = 38.5%

99/00

1999/2000	
	Total (Urban and Rural)
False Alarm – Good Intent	6,498
False Alarm – Other	17,898
Grand Total	59,238

Total number of false alarm in 99/2000 fire service year is: 6,498 + 17,898 = 24,396

The grand total number of emergency call incidents is: 59,238

The percentage of false alarm calls is 24,396 / 59,238 = 41.2%

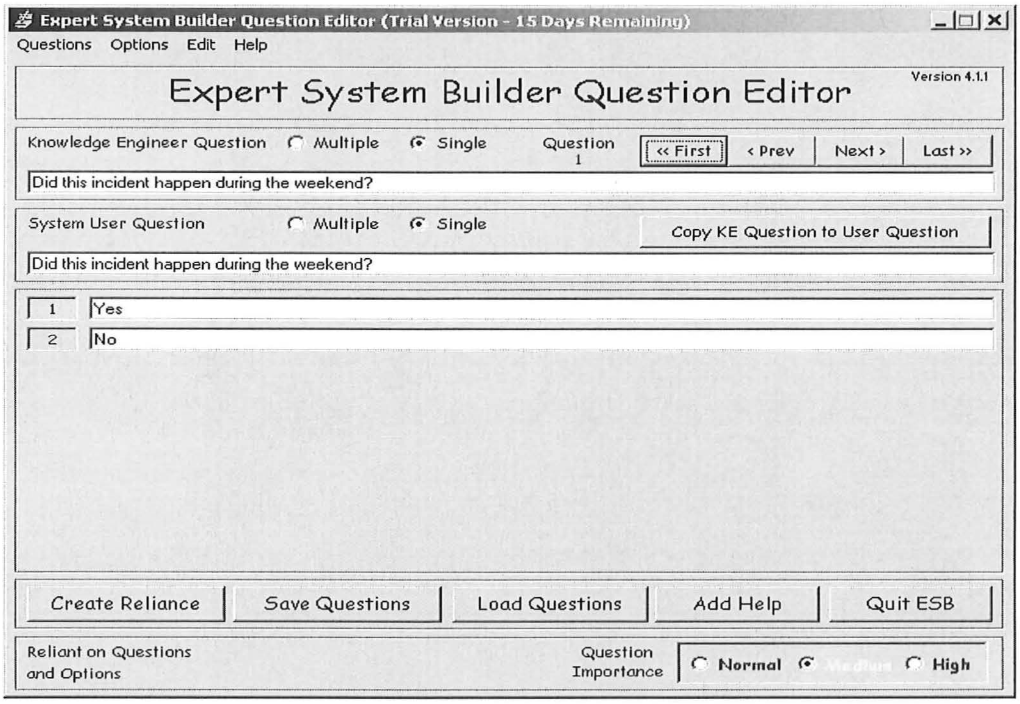
Appendix 3. Fire Stations Covered in Each Fire Region

Region	Fire stations in the coverage area
Northland	Whangarei, Hikurangi, Tutukaka Coast, Ruakaka, Dargaville, Ruawai, Portland, Kaikoke, Kaeo, Kerikeri, Kohukohu, Okaihau, Rawene, Kaitaia, Mangonui, Kawakawa, Paihia, Russell, Maungaturoto, Kaiwaka, Waipu, Omapere, Mangawhai
Auckland	Auckland City, Waiheke, Pukekohe, Mercer, Tuakau, Waiuku, Helensville, Warkworth, Leigh, Wellsford, Silverdale, Mangatawhiri, Kumeu, Piha, Waiatarua, Huia, Mangatangi, Onewhero, Potumamohoe, Port Waikato, Kawakawa Bay, Auckland South, Auckland East, Auckland West, Auckland North, Maramarua
Bay-Waikato	Hamilton, Ngaruawahia, Cambridge, Huntly, Te Kauwhata, Matamata, Morrinsville, Te Aroha, Raglan, Te Awamutu, Kawhia, Te Kuiti, Bennydale, Otorohanga, Pio Pio, Tauranga, Thames, Coromandel., Ngatea, Tairua, Tapu, Whitianga, Paeroa, Waihi/Waihi Beach, Whangamata, Katikati, Omokoroa, Te Puke, Kawerau, Whakatane, Edgecumbe, Matata, Taneatua, Opotiki, Rotorua, Murupara, Putaruru, Mangakino, Tirau, Tokoroa, Taupo, Turangi, Ohura, Owhango, Manunui, Kaingaroa, Reporoa
Arapawa	Otaki, Wellington South, Wanuiomata, ParaparaNone, Paekakariki, Waikanae, Wellington North, Eastbourne, Masterton, Carterton, Featherston, Greytown, Martinborough, Eketahuna, Nelson, Blenheim Havelock, Seddon, Picton, Mapua, Richmond, Wakefield, Motueka, Murchison, Takaka, Collingwood, Lower Hutt, Porirua, Rimutaka, Upper Hutt, Tawa, Titahi, Bay, Plimmerton, Newlands, Silverstream, Johnsonville, Chatham, Korori
Transalpine	Christchurch, Kaiapoi, Lincoln, Leeston, Southbridge, Akaroa, Little River, Ambereley, Hawarden, Waikari, Waipara, Ashburton, Methven, Rakaia, Cheviot, Culverden, Hanmer, Waiau, Darfield, Springfield, Kaikoura, Rangiora, Cust, Oxford, Timaru, Fairlie, Lake Tekapo, Geraldine, Pleasant Point, Temuka, St Andrews, Waimate, Glenavy, Twizel, Greymouth, Brunner, Kumara, Ngahere, Blackball, Reefton, Runanga, Hokitika, Franz Josef, Harihari, Whataroa, Ross, Westport, Granity, Karamea, Waimangaroa, Rolleston, Woodend, Fox Glacier, Governors Bay, Sheffield, Chertsey
Southern	Dunedin, Middlemarch, Alexandra, Clyde, Cromwell, Millers Flat, Omakau, Roxburgh, Balclutha, Clinton, Kaitangata, Milton, Owaka, Kurow, Omarama, Otematata, Lawrence, Oamaru, Palmerston, Waikouaiti, Queenstown, Arrowtown, Ranfurly, Naseby, Wanaka, Lake Hawea, Luggate, Duntroon, Invercargill, Tokanui, Riverton, Orepuki, Thornbury, Winton, Edendale, Wyndham, Gore, Mataura, Waikaia, Waikaka, Tapanui, Heriot, Riversdale, Lumsden, Balfour, Mossburn, Otautau, Nightcaps, Ohai, Orawia, Tuatapere, Te Anau, Oban, Bluff, Invercargill Rural
Eastern	Pahiatua, Hawkes Bay, Spare, Waipukurau, Takapau, Waipawa, Dannevirke, Norsewood, Ormondville, Gisborne, Matawai, Te Karaka, Tolaga Bay, Ruatoria, Te Araroa, Tikitiki, Te Puia, Wairoa, Nuhaka
Western	Taumarunui, National Park, Palmerston North, Rongotea, Tokomaru, Feilding, Apiti, Spare, Halcombe, Kimbolton, Levin, Foxton, Foxton Beach, Shannon, Rangiwahia, Woodville, Pongaroa, Wanganui, Waverley, Ratana, Waitotara, Ohakune, Raetihi, Taihape, Mangaweka, Hunterville, Marton, Bulls, New Plymouth, Inglewood, Okato, Urenui, Waitara, Stratford, Eltham, Kaponga, Opunake, Hawera, Manaia, Patea, Okaiawa, Waiouru

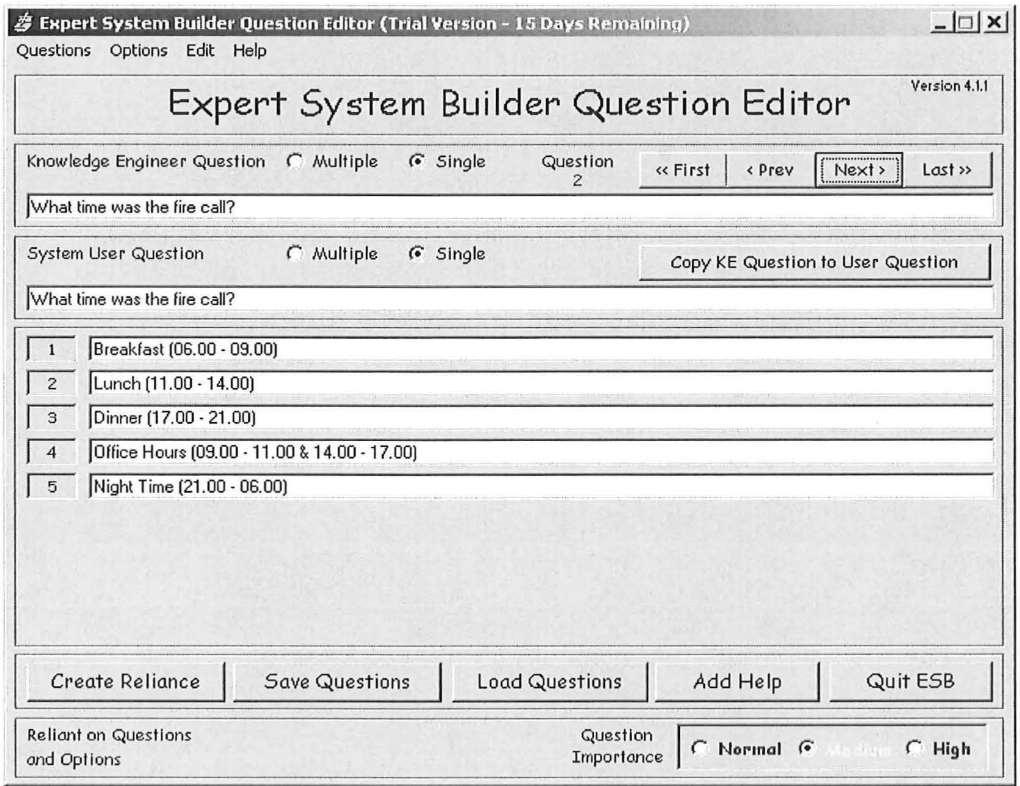
Appendix 4 Question Set of ESB Question Editor

These following figures show the questions entered in ESB Question Editor:

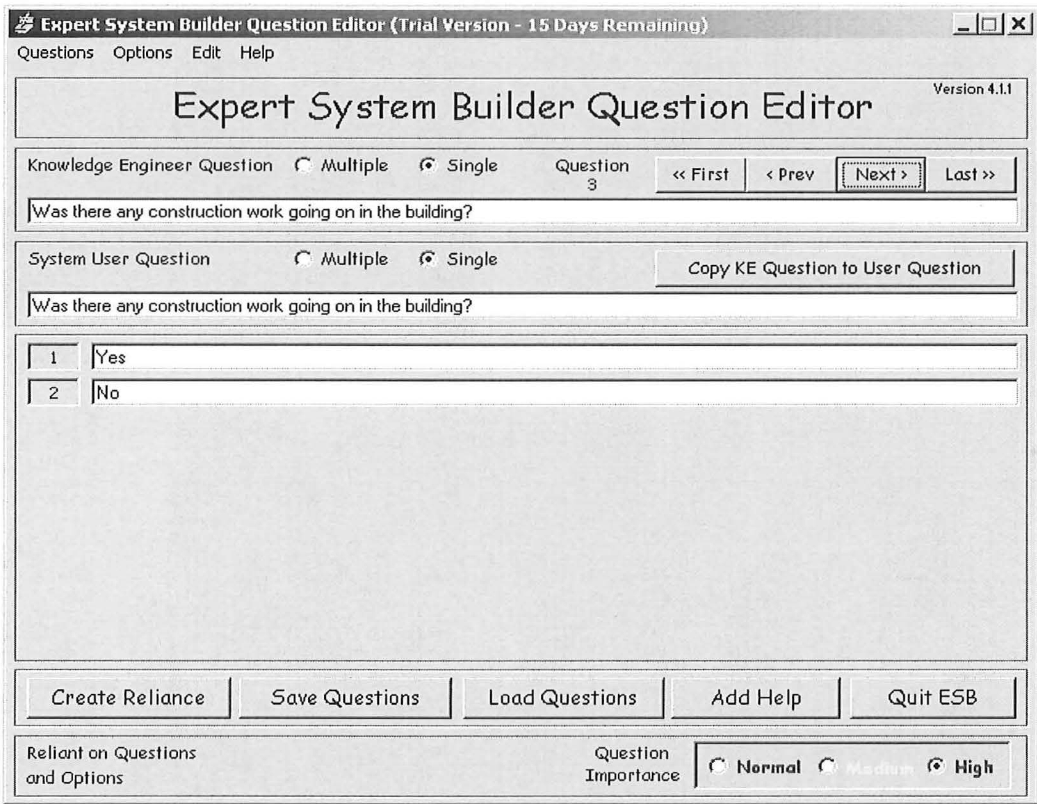
Q1



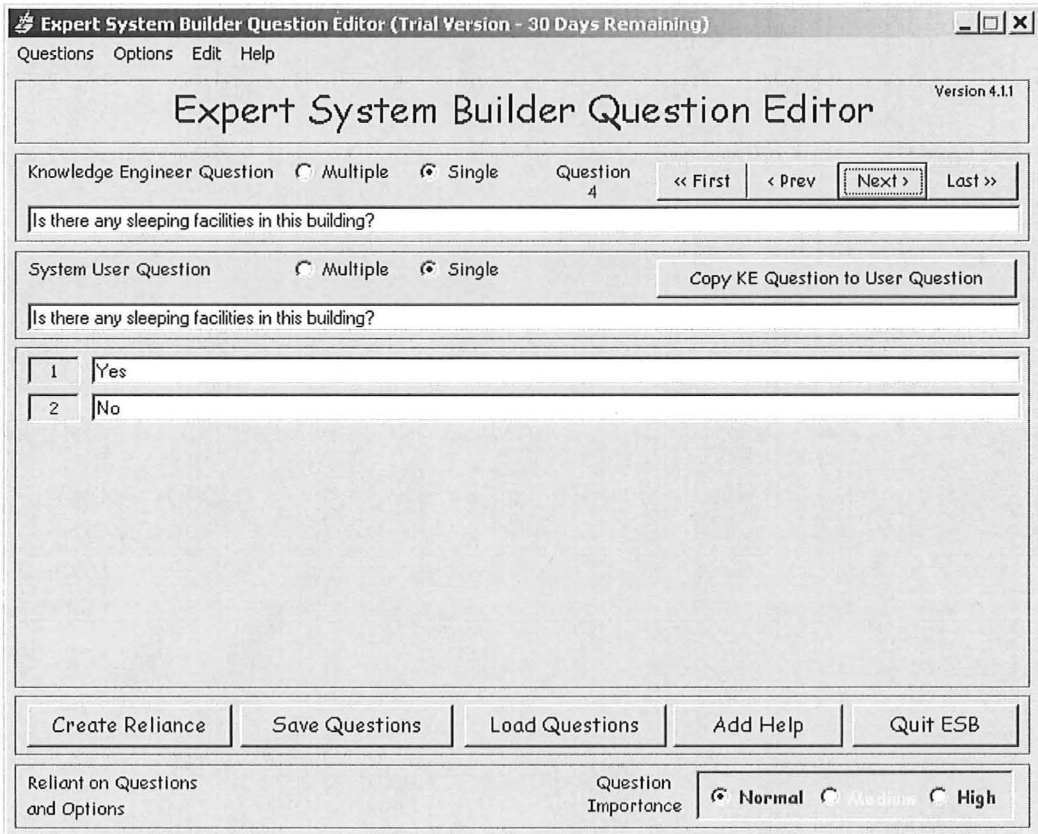
Q2



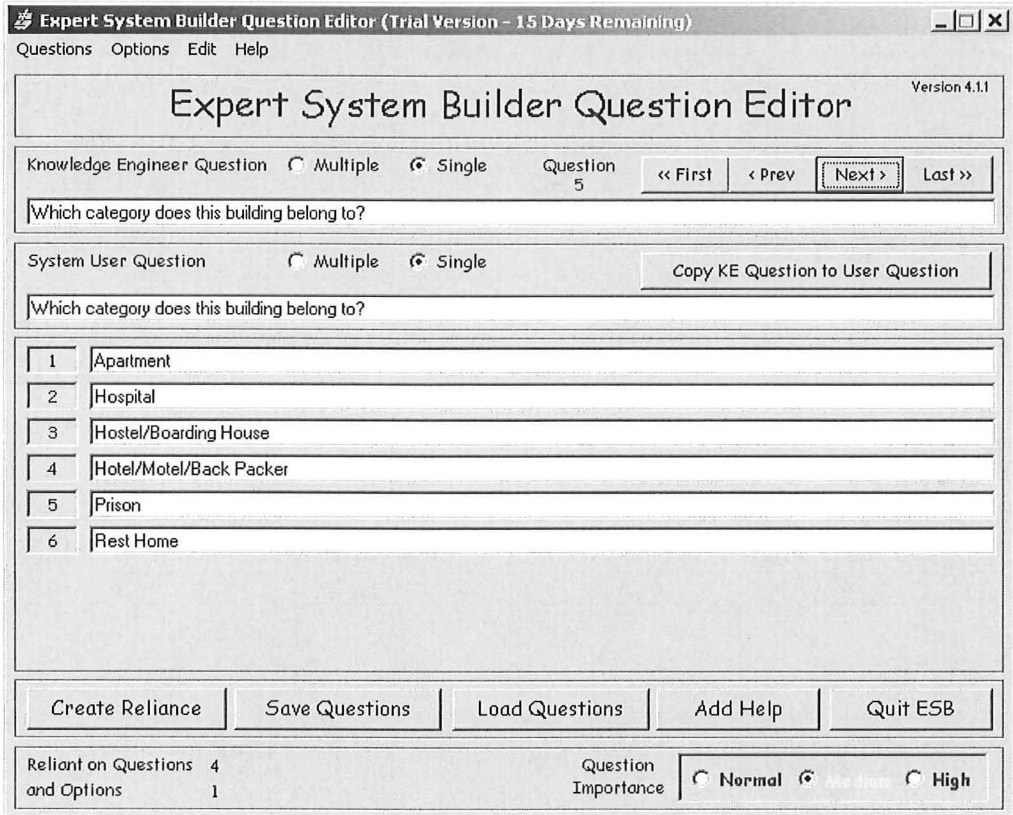
Q3


Expert System Builder Question Editor (Trial Version - 15 Days Remaining)
Questions Options Edit Help
Expert System Builder Question Editor
Version 4.1.1
Knowledge Engineer Question
Multiple
Single
Question
3
« First
‹ Prev
Next ›
Last »
Was there any construction work going on in the building?
System User Question
Multiple
Single
Copy KE Question to User Question
Was there any construction work going on in the building?
1
Yes
2
No
Create Reliance
Save Questions
Load Questions
Add Help
Quit ESB
Reliant on Questions and Options
Question Importance
Normal
High

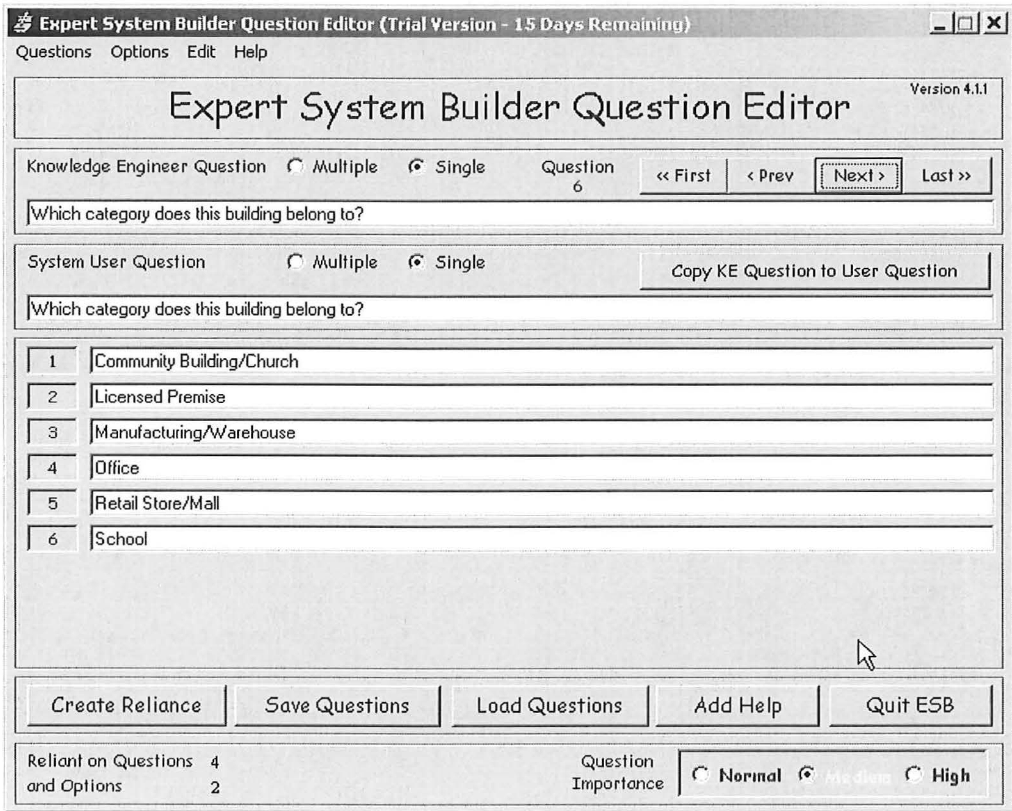
Q4


Expert System Builder Question Editor (Trial Version - 30 Days Remaining)
Questions Options Edit Help
Expert System Builder Question Editor
Version 4.1.1
Knowledge Engineer Question
Multiple
Single
Question
4
« First
‹ Prev
Next ›
Last »
Is there any sleeping facilities in this building?
System User Question
Multiple
Single
Copy KE Question to User Question
Is there any sleeping facilities in this building?
1
Yes
2
No
Create Reliance
Save Questions
Load Questions
Add Help
Quit ESB
Reliant on Questions and Options
Question Importance
Normal
High

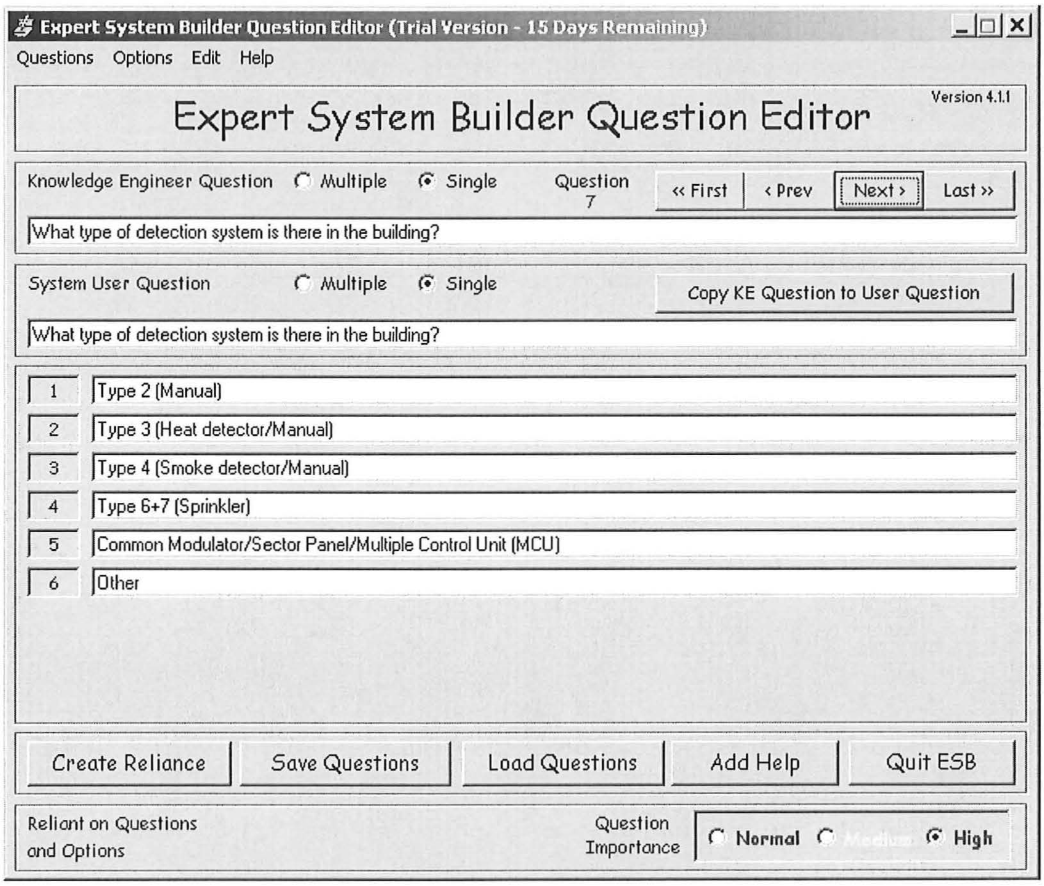
Q5


Expert System Builder Question Editor (Trial Version - 15 Days Remaining)
Questions Options Edit Help
Expert System Builder Question Editor
Version 4.1.1
Knowledge Engineer Question
Multiple
Single
Question 5
« First
‹ Prev
Next ›
Last »
Which category does this building belong to?
System User Question
Multiple
Single
Copy KE Question to User Question
Which category does this building belong to?
1 Apartment
2 Hospital
3 Hostel/Boarding House
4 Hotel/Motel/Back Packer
5 Prison
6 Rest Home
Create Reliance
Save Questions
Load Questions
Add Help
Quit ESB
Reliant on Questions 4
and Options 1
Question Importance
Normal
High

Q6


Expert System Builder Question Editor (Trial Version - 15 Days Remaining)
Questions Options Edit Help
Expert System Builder Question Editor
Version 4.1.1
Knowledge Engineer Question
Multiple
Single
Question 6
« First
‹ Prev
Next ›
Last »
Which category does this building belong to?
System User Question
Multiple
Single
Copy KE Question to User Question
Which category does this building belong to?
1 Community Building/Church
2 Licensed Premise
3 Manufacturing/Warehouse
4 Office
5 Retail Store/Mall
6 School
Create Reliance
Save Questions
Load Questions
Add Help
Quit ESB
Reliant on Questions 4
and Options 2
Question Importance
Normal
High

Q7


Expert System Builder Question Editor (Trial Version - 15 Days Remaining)
Questions
Options
Edit
Help
Version 4.1.1
Expert System Builder Question Editor
Knowledge Engineer Question
Multiple
Single
Question 7
« First
‹ Prev
Next ›
Last »
What type of detection system is there in the building?
System User Question
Multiple
Single
Copy KE Question to User Question
What type of detection system is there in the building?
1 Type 2 (Manual)
2 Type 3 (Heat detector/Manual)
3 Type 4 (Smoke detector/Manual)
4 Type 6+7 (Sprinkler)
5 Common Modulator/Sector Panel/Multiple Control Unit (MCU)
6 Other
Create Reliance
Save Questions
Load Questions
Add Help
Quit ESB
Reliant on Questions and Options
Question Importance
Normal
High

Appendix 5 and Appendix 6 are available on request

Please contact Dr Mike Spearpoint, at the address below if you would like a copy.

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